Chapter 8: Lake Okeechobee Watershed Protection Program

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SUMMARY

Lake Okeechobee, the largest lake in the southeastern United States, is shallow, frequently turbid, eutrophic, and a central component of the hydrology and environment of South Florida. The lake supplies water for agriculture and downstream ecosystems, and provides flood control for surrounding areas. It is also the primary water supply for the Okeechobee Utility Authority and the backup water supply for much of South Florida. Lake Okeechobee is home to migratory water fowl, wading birds, and the federally endangered Everglade snail kite. The lake is also a multi-million dollar recreational and commercial fishery.

Lake Okeechobee has been subject to three long-term impacts: (1) excessive total phosphorus (TP) loads, (2) extreme water level fluctuations, and (3) rapid spread of exotic and nuisance plants in the littoral zone. The South Florida Water Management District (District or SFWMD), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), United States Army Corps of Engineers (USACE), and Florida Fish and Wildlife Conservation Commission (FWC) are working cooperatively to address these interconnected issues in order to rehabilitate the lake and enhance the ecosystem services it provides, while maintaining other societal functions such as water supply and flood control.

Despite the implementation of a FDEP dairy technology-based rule and a performance-based regulatory program for a portion of the watershed, loads to the lake did not decline substantially during the 1990s. As a result, in 2000, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA), which requires the coordinating agencies—the District, FDACS, and FDEP—to work together to address TP loading and exotic species control. The LOPA was subsumed in 2007 by the Northern Everglades and Estuaries Protection Program (NEEPP) [Section 373.4595, Florida Statutes (F.S.)].

This chapter of the *2013 South Florida Environmental Report* (SFER) – *Volume I* provides the Water Year 2012 (WY2012) (May 1, 2011–April 30, 2012) status of the Lake Okeechobee Watershed Protection Program. It includes major issues affecting Lake Okeechobee's in-lake water quality and ecology, and ongoing projects to help address those issues regarding the Lake

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Okeechobee Watershed that fall under the NEEPP. The NEEPP requires annual status reports on the Lake Okeechobee Watershed Protection Program (LOWPP).

WATERSHED UPDATES

The LOWPP is being implemented as part of the NEEPP, which promotes a comprehensive, interconnected watershed approach to protecting the lake and its downstream estuaries (Caloosahatchee and St. Lucie). The watershed protection program is a cooperative effort between the District, FDEP, and FDACS and is currently being implemented.

Major developments and accomplishments under the LOWPP during WY2012 include the following:

1. Numerous efforts have been conducted under the Lake Okeechobee Watershed Construction Project, including (1) completion of the Lakeside Ranch Stormwater Treatment Area (STA) Phase I construction, which is designed to remove phosphorus (P) from stormwater runoff in the Taylor Creek/Nubbin Slough Basin before it enters the lake; (2) two pilot-scale STAs in Taylor Creek and Nubbin Slough; (3) hybrid wetland treatment technology (HWTT), which represents a combination of chemical and wetland treatment technologies to remove TP at sub-basin and farm scales; (4) dispersed water management projects, which include both public and private landowners participating in a variety of efforts that spread excess water across the landscape and require little new construction to retain large cumulative volumes of water; and (5) feasibility studies at the sub-watershed level, which are identifying sub-watershed planning targets and identifying preferred plans to achieve those targets.
2. Research and assessment projects during WY2012 were (1) preliminary work on the tributary water quality trend analysis; (2) baseline soil characterization of the Lakeside Ranch STA Phase I; (3) continued operation and evaluation of six HWTT projects; (4) an initial Watershed Assessment Model application study in the Lake Kissimmee Sub-watershed; (5) new alternative treatment technologies; and (6) continued evaluation of the permeable reactive barrier technology.
3. TP load to the lake from all drainage basins and atmospheric deposition was 377 metric tons (mt) in WY2012. The Lower Kissimmee Sub-watershed contributed 30 percent TP load and 17 percent discharge with a 12 percent drainage area; the Upper Kissimmee Sub-watershed contributed 18 percent TP load and 42 percent discharge with a 30 percent drainage area; and the Taylor Creek/Nubbin Slough Basin contributed 9 percent TP load and 2.5 percent discharge with a 3.5 percent drainage area. The Industrial Canal Basin had the highest unit area load of 1.48 pounds per acre (lb/ac), followed by S-154C (0.66 lb/ac), L61-E Basin (0.61 lb/ac), and Taylor Creek/Nubbin Slough Basin (0.57 lb/ac). The C-40 Basin displayed the highest flow-weighted TP concentrations [929 parts per billion (ppb)], followed by the C 41 Basin (899 ppb). The current five-year average (WY2008–WY2012) TP load was 387 mt, which is about 2.8 times greater than the 140 metric tons per year (mt/yr) Total Maximum Daily Load (TMDL).
4. P concentrations in the lake water column have declined each year after reaching a maximum yearly average value of 233 ppb in 2005. In WY2012, the average value was 92 ppb, and such a low average annual value has not been observed since 1993.
5. Total nitrogen (TN) load to the lake from all drainage basins and atmospheric deposition was 4,620 mt in WY2012. The Upper Kissimmee, Lower Kissimmee, and Lake Istokpoga sub-watersheds contributed the largest TN loads and discharges to the lake. The Industrial Canal, L-61E, L-59W, and L-60W basins had the highest unit area TN load in terms of pounds per acre. Nicodemus Slough, S-2, C40, and C41 basins displayed the highest flow-weighted TN concentrations.

The flow of water to Lake Okeechobee was 1.944 million acre-feet or about 2,399 million cubic meters (m^3) in WY2012, which is 80 percent of the baseline average (calendar years 2001–2009) of 2.433 million ac-ft or about 3,000 million m^3. Lake Okeechobee began the water year at an elevation of 10.92 feet National Geodetic Vertical Datum of 1929 (ft NGVD) or 3.33 meters. Because of the low water levels and the dry conditions from early in the 2011 calendar year, the District implemented modified Phase I and II water restrictions in March 2011. Low lake levels continued until an October rain event. On November 11, 2011 the restrictions were lifted because water levels were now well above the Water Shortage Management criteria. The lake ended WY2012 in the Water Management Sub-band at an elevation of 11.68 ft NGVD. Detailed information on regional hydrology during WY2012 is presented in Chapter 2 of this volume.

ECOLOGY

Lake Okeechobee

While submerged aquatic vegetation (SAV) in Lake Okeechobee increased to 36,325 acres from the previous year's total of 27,388 total acres, much of this increase was the result of increased coverage by the macro alga *Chara* spp. These changes appear to be a continuation of a trend noted last year related to generally lower lake stages resulting from both the implementation of the interim 2008 Lake Okeechobee Regulation Operating Schedule (2008 LORS) and recent dry conditions. SAV is being replaced by spike rush (*Eleocharis* spp.) and other emergent vegetation in previously open water, nearshore areas, while SAV, especially *Chara* spp., colonizes areas further offshore, which were previously too deep to allow sufficient light penetration to support the growth of SAV. It is unclear what these shifts in the areal coverage of emergent vegetation, vascular SAV, and non-vascular SAV are having on habitat values in the littoral and nearshore zones of Lake Okeechobee, although it is clear that conditions are substantially better than they were during the generally higher lake stages that characterized the mid- to late 1990s, or in the years immediately following the hurricanes of 2004 and 2005.

Algal bloom activity appeared to be quite low this past year, with only several instances of chlorophyll concentrations high enough to be indicative of bloom conditions encountered, and no blue-green algal toxins in excess of the detectable limit noted.

The Lake Okeechobee fishery appears to be in good condition. Both nearshore and pelagic zone sport fish and forage fish populations continue to recover from the effects of the hurricanes of 2004 and 2005. Overall, values for most species were not as high as they were the previous year, but remained comparable to historic pre-hurricane results. The black crappie population, whose recovery has lagged relative to other important lake species, appears to be continuing a modest improvement.

Wading bird utilization of the lake for foraging was very low this year when compared to the previous year's values. The presumption is that the low water levels that preceded the past winter inhibited the production of the small fish and other aquatic organisms favored by wading birds as food items and therefore resulted in an inadequate prey base to support much foraging activity; a situation that has been demonstrated to occur in other Greater Everglades ecosystems. Wading bird nesting effort was quite high; however nesting success was very poor. Nevertheless, Lake Okeechobee was one of the few places in the Greater Everglades landscape that had successful nesting this year, reinforcing the importance of an ecologically sound lake as a functional component of the Greater Everglades ecosystem.

Lake Istokpoga

Annual SAV monitoring was performed in Lake Istokpoga in spring 2012. SAV occurred in 215 of the 447 sampled grids (48 percent). As in the preceding year, the most commonly observed plants were hydrilla, an invasive exotic, and the native plant tape grass. Other observed but less common species included bladderwort, pondweed, naiad, and coontail. In the 2012 sampling event, hydrilla declined in both areal coverage and density relative to 2011, indicating that ongoing hydrilla control efforts by the FWC appear to be meeting with success.

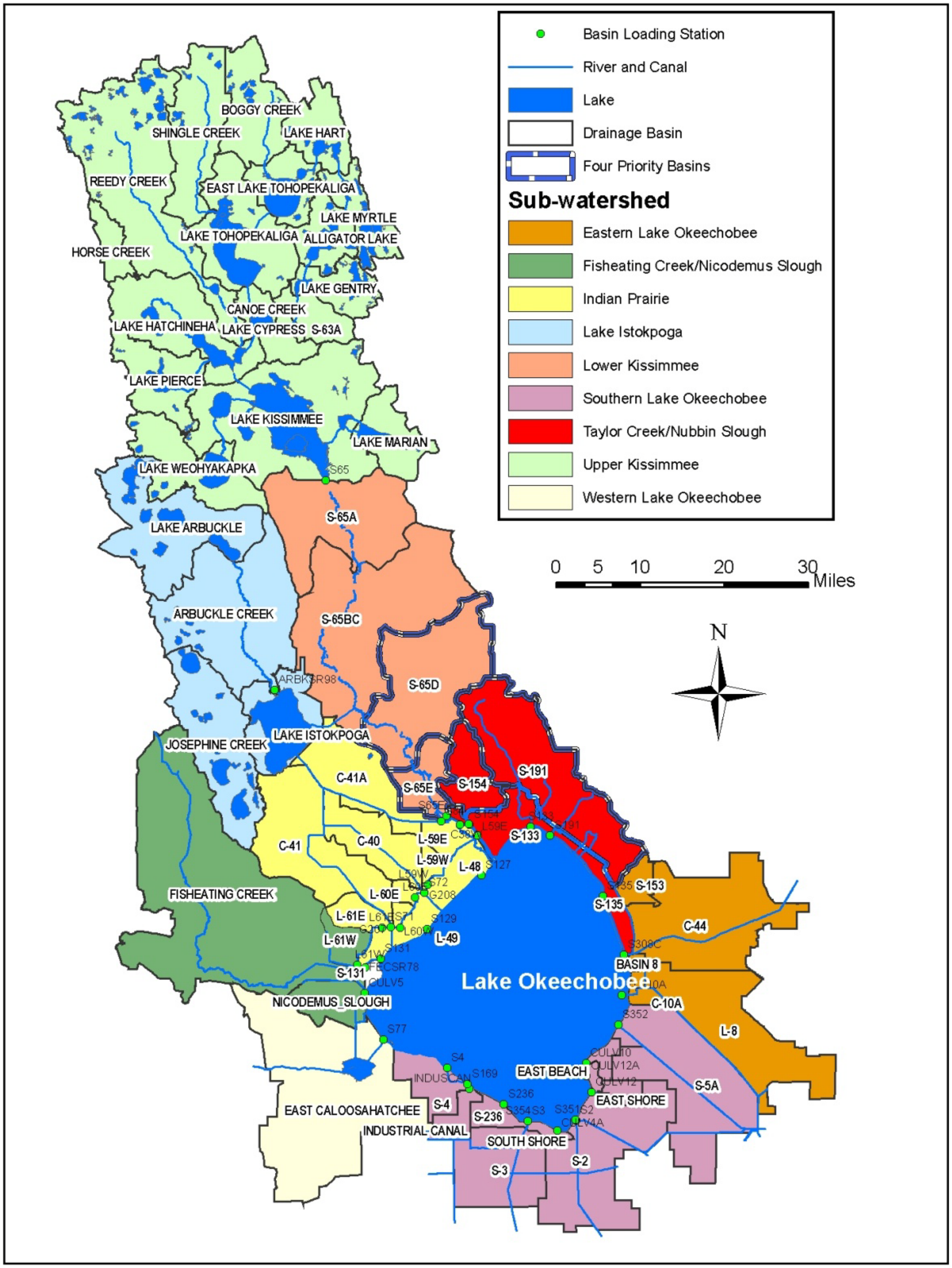
INTRODUCTION

Lake Okeechobee (located at 27° North latitude and 81° West longitude) has a surface area of 445,560 acres (ac) [1,803 square kilometers (km^2)], and is extremely shallow, with a mean depth of 8.9 feet (ft) [2.7 meters (m)] and maximal depth of 18 ft (5.5 m) (James et al., 1995). The lake is a central part of the interconnected South Florida aquatic ecosystem and the United States Army Corps of Engineers (USACE) regional flood control project. Lake Okeechobee receives water from a 5,400 square mile (14,000 km^2) watershed that includes four distinct tributary systems: Kissimmee River Valley, Lake Istokpoga–Indian Prairie/Harney Pond, Fisheating Creek, and Taylor Creek/Nubbin Slough. With the exception of Fisheating Creek, all major inflows to Lake Okeechobee are controlled by gravity-fed or pump-driven water control structures (**Figure 8-1**). These four major tributary systems are generally bound by the drainage divides of the major water bodies and are further divisible into 61 drainage basins and grouped by nine sub-watersheds based on hydrology and geography (**Figure 8-1**).

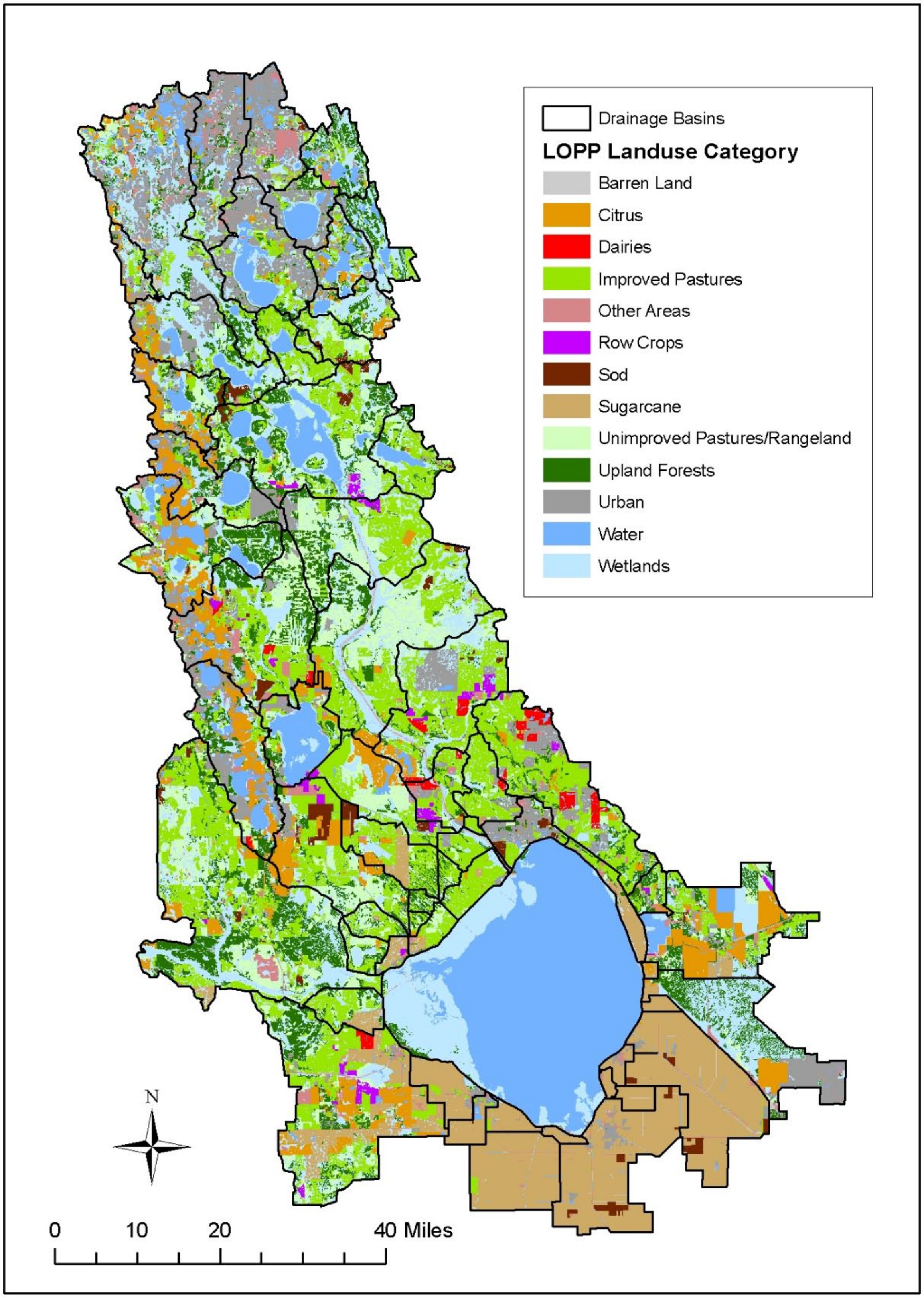
The nine sub-watersheds of the Lake Okeechobee Watershed are the Upper Kissimmee (above structure S-65), Lower Kissimmee (between structures S-65E and S-65), Taylor Creek/Nubbin Slough (S-191, S-133, S-135, S-154, and S154C basins), Lake Istokpoga (above structure S-68), Indian Prairie (C-40, C-41, C-41A, L-48, L-49, L-59E, L-59W, L-60E, L-60W, L-61E, and S-131 basins), Fisheating Creek (Fisheating Creek, L-61W, and Nicodemus Slough basins), Eastern Lake Okeechobee (C-44, S-153, and L-8 basins), Western Lake Okeechobee (C-43 Basin), and Southern Lake Okeechobee [includes Everglades Agricultural Area (EAA) and Chapter 298 Districts] (**Figure 8-1**). One update to this figure was to code the L-61W Basin as part of Fisheating Creek Sub-watershed instead of Indian Prairie Sub-watershed.

The Upper Kissimmee, Lower Kissimmee, Taylor Creek/Nubbin Slough, Lake Istokpoga, Indian Prairie, and Fisheating Creek sub-watersheds primarily drain into Lake Okeechobee by gravity. The S-133 Basin (part of the Taylor Creek/Nubbin Slough Sub-watershed) and other urban areas can also pump water into the lake from the north. When high lake stages make gravity flows impossible, urban areas north of the lake are drained via pumps. The Eastern and Western Lake Okeechobee sub-watersheds contribute flow by gravity, but only when Lake Okeechobee water levels are below 14.5 ft and 11.5 ft, respectively, in relation to the National Geodetic Vertical Datum of 1929 (NGVD).

The Lake Okeechobee Watershed is dominated by agricultural land uses that account for 51 percent of the total area (1.7 million ac); followed by natural areas including wetlands, upland forests, and water bodies (36 percent or 1.2 million ac); and urban areas (12 percent or approximately 410,000 ac) (**Figure 8-2**). Agricultural land uses can be further classified as (1) improved pasture (20 percent) for beef cattle grazing and unimproved pasture/rangeland (9 percent) north of the lake; sugarcane production (12 percent) south of the lake within the EAA; (2) citrus groves (7 percent) located primarily within the eastern portion of the watershed and Lake Istokpoga Basin; and (3) sod farms, row crops, dairies, and “other areas,” which make up the remaining (three percent) land uses within the watershed.



173 **Figure 8-1.** The Lake Okeechobee Watershed detailing sub-watersheds, major
174 hydrologic features, and structure locations where total phosphorus (TP) loads were
175 determined from tributary basins that drain into Lake Okeechobee (green dots).



176 **Figure 8-2.** Land use distribution in the Lake Okeechobee Watershed.

Although dairy farms in the northern basins cover less than one percent of the land use area, they represent a considerable source of phosphorus (P) to some tributaries and up to five percent of the total external total phosphorus (TP) loading to the lake (Bottcher, 2006). The nutrient levels in surface water runoff are directly related to land use and land management practices within the watershed (Zhang et al., 2002; Hiscock et al., 2003). The South Florida Water Management District (District or SFWMD) uses the Florida Land Use, Cover, and Forms Classification System to define land use types. The District's minimum mapping unit standards for land cover and land use are 5 ac for upland and 2 ac for wetlands. For example, a wetland area less than 2 ac and located within pastures will be included in the pasture total.

Lake Okeechobee provides numerous services to diverse users with tremendous economic interest in its health and fate. The lake provides water supply to agriculture, and downstream estuarine ecosystems. It is also the primary water supply for the Okeechobee Utility Authority and the backup water supply for much of South Florida. It supports multimillion-dollar sport and commercial fisheries, and various recreational activities. It also provides habitat for migratory waterfowl, wading birds, alligators (*Alligator mississippiensis*), and the Everglade snail kite (*Rostrhamus sociabilis plumbeus*) (Aumen, 1995). The lake is also used for flood control during the wet season (June–October) and water supply during the dry season (November–May). The lake faces three major environmental challenges: (1) excessive TP loads, (2) extreme water level fluctuations, and (3) the rapid spread of exotic and nuisance plants.

This chapter provides a comprehensive update and discussion of lake and watershed conditions presented in Chapter 8 of the *2012 South Florida Environmental Report* (SFER) – *Volume I*, focusing on water quality, water levels, aquatic vegetation, and P control activities. Results of recently completed research projects are presented, as well as the status for ongoing watershed and in-lake management projects. More information about the Kissimmee Chain of Lakes and the Kissimmee River can be found in Chapter 9 of this volume. Additional information on P source control programs and exotic species status in South Florida are presented in Chapters 4 and 7 of this volume, respectively.

OVERVIEW OF LAKE OKEECHOBEE WATERSHED PROTECTION PROGRAM

Passed in 2000, the Lake Okeechobee Protection Act (LOPA) [Section 373.4595, Florida Statutes (F.S.)] established a restoration and protection program for the lake. This program addresses the reduction of TP loading to the lake from both internal and external sources. In 2007, the legislature amended the LOPA with Section 373.4595, F.S., now known as the Northern Everglades and Estuaries Protection Program (NEEPP). The NEEPP promotes a comprehensive, interconnected watershed approach to protect Lake Okeechobee and the Caloosahatchee and St. Lucie Rivers (SFWMD et al., 2008). The NEEPP includes the Lake Okeechobee, Caloosahatchee River, and St. Lucie River watershed protection programs. These programs identify and implement programs and projects necessary to achieve water quality and quantity objectives for the watersheds. Water quality objectives are based on Total Maximum Daily Loads (TMDLs) established by the Florida Department of Environmental Protection (FDEP), while storage targets are aimed at achieving appropriate water levels in Lake Okeechobee and salinities within the estuaries. Details on river watershed protection program elements and updates are presented in the 2012 SFER – Volume I, Appendices 10-1 and 10-2. A cross-reference list for NEEPP reporting is provided in Appendix 8-1 of this volume.

The District, in cooperation with the FDEP and Florida Department of Agriculture and Consumer Services (FDACS), collectively known as the coordinating agencies, completed a Lake Okeechobee Protection Plan and reevaluate the plan every three years as part of the NEEPP. The

Lake Okeechobee Protection Plan was originally submitted to the Florida legislature on January 1, 2004 (SFWMD et al., 2004). The plan was considered the best strategy, utilizing the best available technologically, for reducing nutrients, particularly for P, in Lake Okeechobee and its downstream receiving waters. The water quality goal of the Lake Okeechobee Watershed Protection Program (LOWPP) is the Lake Okeechobee TMDL of 140 metric tons (mt) of TP per year, which consists of 105 mt of TP from the watershed tributaries and 35 mt from atmospheric deposition.

The Lake Okeechobee Watershed Construction Project (LOWCP) Phase II Technical Plan was submitted to the Florida legislature in February 2008 as required by the NEEPP (SFWMD et al., 2008) and is currently being implemented. The technical plan identifies construction projects and on-site measures that prevent or reduce pollution at the source. The plan includes source controls [i.e. Best Management Practices (BMPs)] and several sub-regional and regional technologies, such as stormwater treatment areas (STAs) and alternative treatment technologies, to improve the quality of water within the watershed and of that delivered to Lake Okeechobee. Several measures are also included in the plan to improve both water levels within the lake and the quantity and timing of discharges from Lake Okeechobee to the Northern Estuaries to achieve more desirable salinity ranges. These measures include reservoirs, dispersed water management projects, aquifer storage and recovery, and deep well injection. Most recently, coordinating agencies completed the 2011 Lake Okeechobee Protection Plan Update to fulfill the legislative requirement for the three-year update (SFWMD et al., 2011). The 2011 update report is available at www.sfwmd.gov/northerneverglades. The update focuses on the progress of the coordinating agencies in reducing TP loads consistent with the TMDL established for the lake, as well as increasing watershed storage to achieve healthier lake levels and to reduce harmful discharges to the estuaries.

Elements of the LOWPP include three main components: (1) the LOWCP (Phase I and Phase II Technical Plans), (2) the Lake Okeechobee Watershed Phosphorus Control Program, and (3) the Lake Okeechobee Watershed Research and Water Quality Monitoring Program. In addition, the LOWPP includes a Lake Okeechobee Exotic Species Control Program and a Lake Okeechobee Internal Phosphorus Management Program. A brief description of these elements is provided below and a diagram illustrating the relationship among the protection programs, associated elements, and projects is presented in **Figure 8-3**.

The NEEPP requires the District to submit an annual progress report to the Florida legislature. This chapter constitutes the twelfth annual report to the legislature summarizing the hydrology, water quality, and aquatic habitat conditions of the lake and its watershed based on the results of research and water quality monitoring, and the status of the LOWCP. The annual progress report requirement of the NEEPP in regards to the Lake Okeechobee Watershed is fulfilled by this chapter. NEEPP reporting for the St. Lucie and Caloosahatchee river watersheds is provided in Chapter 10 of this volume. More details on exotics within the District boundaries and certain source control programs for surrounding watersheds are presented in Chapters 7 and 4 of this volume, respectively. In addition, state funding appropriations and expenditures for the LOWPP during Fiscal Year 2012 (FY2012) (October 1, 2011–September 30, 2012) are included in this chapter. The Northern Everglades Annual Work Plan for FY2013 is also provided as Appendix 8-2 of this volume.

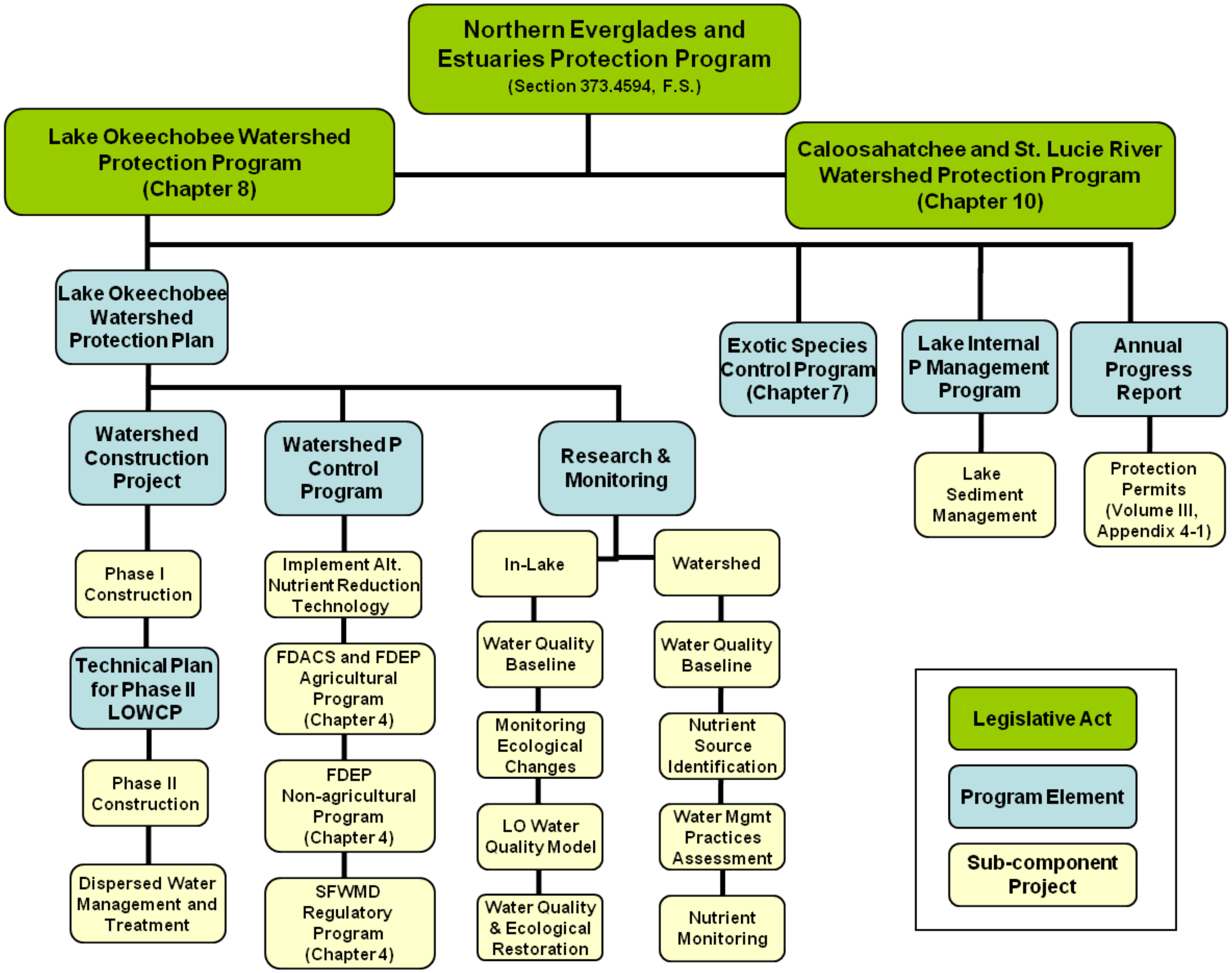


Figure 8-3. Northern Everglades and Estuaries Protection Program (NEEPP) structure, detailing the Lake Okeechobee Watershed Protection Program's (LOWPP) elements and projects. [Note: F.S. – Florida Statutes; LOWCP – Lake Okeechobee Watershed Construction Project; P – phosphorus; Alt. – Alternate; FDACS – Florida Department of Agricultural and Consumer Services; FDEP – Florida Department of Environmental Protection; SFWMD – South Florida Water Management District; and LO – Lake Okeechobee.]

WATERSHED CONSTRUCTION PROJECT

The LOWCP identifies a suite of best available water quality and storage projects to improve hydrology, water quality, and aquatic habitats within the watershed. It is required under NEEPP and identifies specific activities to provide immediate load reductions to Lake Okeechobee (Phase I) and the development of the Phase II Technical Plan, which identified the best mix of regional-, sub-regional-, and parcel-scale alternatives to help achieve the LOWPP water quality and storage goals. It includes STAs, innovative nutrient control technologies such as hybrid wetland treatment technology (HWTT), nutrient source controls (i.e., agricultural and urban BMPs), and dispersed water storage on private land to improve water quality. For a detailed description of the LOWCP and the associated activities see the 2011 Lake Okeechobee Protection Plan Update (SFWMD et al., 2011). Updates on the LOWCP activities are provided under the *Watershed Construction Project Update* section of this chapter.

WATERSHED PHOSPHORUS CONTROL PROGRAMS

The Lake Okeechobee Watershed Phosphorus Control Program is a multifaceted program that includes (1) continued implementation of regulatory and voluntary agricultural and non-agricultural BMPs; (2) development and implementation of improved BMPs; (3) improvement and restoration of hydrologic function of natural and managed systems; and (4) use of alternative technologies for nutrient reduction. The District, FDEP, and FDACS cooperatively implement this program and coordinate with existing regulatory programs, including the Lake Okeechobee Works of the District Permitting Program [Chapter 40E-61 Florida Administrative Code (F.A.C.)], FDEP Dairy Rule (Chapter 62-670.500, F.A.C.), and Everglades Forever Act [Section 373.4592(13), F.S.], through an interagency agreement. Under NEEPP legislation, the FDACS implements an incentive-based BMP program on agricultural lands within the Lake Okeechobee Watershed; the FDEP is responsible for overseeing the FDACS and District agricultural and non-agricultural BMP programs; and the District is responsible for implementing TP reduction technology projects and a nonpoint regulatory source control program that focuses on TP discharges from rule-specified agricultural and non-agricultural land uses in the watershed. More details about the Lake Okeechobee Watershed Phosphorus Control Program are provided in the 2011 Lake Okeechobee Protection Plan Update (SFWMD et al., 2011). Source control activities for Water Year 2012 (WY2012) (May 1, 2011–April 30. 2012) and anticipated 2013 activities are presented in Chapter 4 of this volume. Implementation of alternative nutrient reduction technologies are discussed in the *Watershed Assessment, Monitoring and Research* section of this chapter.

RESEARCH AND WATER QUALITY MONITORING PROGRAM

The NEEPP requires the agencies coordinating the LOWPP to develop strategies to achieve the TP TMDL for Lake Okeechobee and calls for a comprehensive research and monitoring program to assess and track the status of these strategies. The agreement among the coordinating agencies states that the District will be responsible for maintaining a monitoring network for tracking progress to achieve the basin and sub-basin TP reduction targets for the collective source control programs for the Lake Okeechobee Watershed. Monitoring for source control performance is discussed in Chapter 4 of this volume.

A research and water quality monitoring program was developed by the District in cooperation with the other coordinating agencies to (1) collect data to establish long-term water quality trends in the Lake Okeechobee Watershed; (2) develop a water quality model for the lake; (3) continue to identify and quantify P sources; (4) assess water management practices within the watershed; (5) evaluate the feasibility of alternative nutrient removal technologies; and (6) assess the relationship between water volumes and timing from the watershed, water level changes in the lake, and the timing and volume of water delivered to the estuaries. The last component was documented in the Phase II technical plan. The update for other components is described in the *Watershed Assessment, Monitoring and Research* section of this chapter.

EXOTIC VEGETATION CONTROL

Each year, the District aggressively treats exotic vegetation in Lake Okeechobee. This is done to protect threatened native habitat and to restore areas of the marsh that have been impacted by exotic species. The herbicides imazapyr and glyphosate, which are registered for use in aquatic environments by the federal government and have low toxicity to non-plant organisms, are used to maintain exotics at low levels. As a result, vegetation management activities have altered the marsh landscape in a generally positive manner.

One particular species, torpedograss (*Panicum repens*), exists in dense monocultures and has covered tens of thousands of acres in the upper elevation regions of the marsh. During periods of low lake stage, prescribed burns were set to remove most of the aboveground biomass and stress underground rhizomes. New plants that emerged rapidly from thick underground rhizomes were then treated with herbicides while they were small [(20–30 centimeters (cm)] and actively growing. With this management approach, very little dead biomass remains after treatment. Dierberg (1992) indicated that the decomposition of such emergent vegetation would not add much P to the open water column.

More than 10,000 ac of torpedograss were treated with this method from 2004 to 2006, and more than 20,000 ac of torpedograss were treated from 2007 to 2009. An additional 15,000 ac were treated from 2010 to date. Historic treatment efficacy has varied, but the level of control remains high in many areas several years after treatment. Without these treatments, dense monocultures would remain in the upper elevation regions of the marsh. Although torpedograss is still present in many areas, its coverage has declined dramatically. Native plant communities have colonized some of the treated sites and monthly wading bird surveys conducted in 2010 have documented thousands of birds foraging in shallow open water areas previously affected by torpedograss.

Two new exotic species of concern in Lake Okeechobee are tropical watergrass *(Luziola subintegra*) and West Indian marsh grass (*Hymenachne amplexicaulis*). Both are now being actively treated. More information regarding the status of exotic species in the District is presented in Chapter 7 of this volume. Additional exotic vegetation treatments are noted throughout this chapter under area-specific sections.

INTERNAL PHOSPHORUS MANAGEMENT PROGRAM

P-rich sediments have accumulated in Lake Okeechobee over several decades. The current volume of these P-rich sediments in the lake is estimated at 260 million cubic yards or 199 million cubic meters (m^3). TP loads from these sediments to the water column will delay the response of the lake to significant reductions in external TP loads as NEEPP-sponsored projects and others are completed within the Lake Okeechobee Watershed.

Internal P loading in Lake Okeechobee remains a challenge. Some in-lake P management strategies identified in the Lake Okeechobee Protection Plan include sediment dredging, muck removal scraping and tilling, creation of in-lake islands or littoral zones near outlets, and chemical treatment. The LOPA required a study to examine the engineering, ecological, and economic feasibility of managing these sediments (Blasland, Bouck and Lee, Inc., 2003). It was determined that any management strategy would be temporary unless the external loads were reduced to meet the Lake Okeechobee TP TMDL. Both sediment removal by lake-wide dredging and chemical treatment with aluminum sulfate or similar compound were evaluated and deemed not cost-effective. However, water quality model results also suggest that once the TMDL is met, the water quality in-lake goal of 40 parts per billion (ppb) — as established by the TMDL and described by Havens and James (1997) and Havens and Walker (2002) — will take decades to achieve (James and Pollman, 2011). Additionally, to evaluate the effectiveness of chemical compounds on reducing P release from Lake Okeechobee mud sediments, laboratory studies were completed in 2008 using four chemical compounds [alum (aluminum sulfate), calcium hydroxide ($CaOH_2$), calcium carbonate ($CaCO_3$), and ferric chloride ($FeCL_3$)], each at four concentration levels (Golder Associates, Inc., 2008). Further larger-scale field tests using both of these chemicals and others containing organic polymer compounds have been recommended. More details of these studies are available in the Lake Okeechobee Protection Plan Update (SFWMD et al., 2011).

The ability to investigate these ideas is limited at this time due to funding constraints. Staff will pursue these approaches within current data and skill limitations. The coordinating agencies included an in-lake P management study as a near-term project in the Lake Okeechobee Protection Plan Update that would review the recommendations from the 2003 feasibility study, and evaluate and compare new concepts and technologies against those from the previous report. Permitting requirements and potential limitations associated with these options would also be evaluated and new recommendations would be made for implementation. This project is contingent on funding availability.

WATERSHED CONSTRUCTION PROJECT UPDATE

This section provides updates to the LOWCP activities during WY2012. Background information and more details on specific activities can be found in the 2011 Lake Okeechobee Protection Plan Update (SFWMD et al., 2011), located at www.sfwmd.gov/northerneverglades.

LAKESIDE RANCH STORMWATER TREATMENT AREA

The Lakeside Ranch STA is in the Taylor Creek/Nubbin Slough Sub-watershed, which was identified in the Lake Okeechobee Protection Plan as a priority sub-watershed. This project, expedited under the NEEPP, is a 2,700-ac STA in western Martin County on lands adjacent to Lake Okeechobee (**Figure 8-4**). This STA is anticipated to be one component of the tentatively selected plan chosen for the Lake Okeechobee Watershed Comprehensive Everglades Restoration Plan (CERP) project. More information on the restoration plan is available at http://www.evergladesplan.org/pm/projects/proj_01_lake_o_watershed.aspx).

The Lakeside Ranch STA Project is designed in two phases, which combined are expected to reduce TP loading to the lake by 19 mt annually. Phase I involves STA North, canal improvements, and the installation of the S-650 pump station. The pump station will be able to pump water at a rate of 250 cubic feet per second (cfs). Canal improvements have been made along the L-63 and L-64 levees. Phase I also includes the development of a northern STA, consisting of three treatment cells with an effective treatment area of 919 ac. Existing state appropriations are being used for Phase I. Phase II includes the construction of a southern STA with an effective treatment area of 788 ac, a new pump station at structure S-191, and a discharge canal. Phase II of the STA will also be able to recirculate water from the lake, which may provide potential for internal P removal. Phase II implementation is subject to future funding.

The total investment for the construction of Phase I STA is about $22.8 million. Construction of the Phase I was substantially completed in March 2012. The five-day pump tests were successfully conducted in June 2012 and the final commissioning tests and final inspection are also complete. Start-up operation of the STA is anticipated to begin in WY14 in summer 2013 once wetland vegetation and associated P uptake mechanisms are established in the STA cells.

Final design of Phase II STA South was completed in December 2011. The final design for the S-191A pump station (Phase II) was completed in February 2012.

Figure 8-4. Location and layout of Lakeside Ranch STA.

TAYLOR CREEK AND NUBBIN SLOUGH STAS

The LOWCP includes two pilot-scale STAs, one of which is the Taylor Creek STA (**Figure 8-5**). Constructed in April 2006, this STA is a long, narrow enclosure located about two miles north of the city of Okeechobee in central Okeechobee County. It is bordered on the east by U.S. Highway 441 and the west by Taylor Creek. The STA is approximately 142 ac with an effective treatment area of 118 ac. It is divided into two cells in series and is expected to remove about 9 percent of the P load of Taylor Creek at the inflow to the STA (Stanley Consultants, Inc., 2003). The USACE is the federal sponsor of the project and was responsible for the construction and preliminary operations of the STA. As local project sponsor, the District currently operates the facility under its own operating permit from the FDEP.

Flow-through operations at Taylor Creek STA were initiated on June 26, 2008. After that time, the facility continued operating in a discharge mode until February 24, 2009, when pumping and discharge activities were suspended due to culvert failure at the outfall structure. Construction repairs to the failed culvert kept the STA stagnant for almost 20 months. Following completion of the repairs on August 23, 2010, and a demonstration of compliance with predischarge requirements, flow-through operations at the STA resumed on September 8, 2010. The STA has been in flow-through mode since that date. As of the end of WY2012, the Taylor Creek STA has removed 3.46 mt of TP out of the 11.59 mt it received over 28 months of flow-through operation. The STA was designed to remove 2.02 mt of TP from the Taylor Creek drainage basin per year (Stanley Consultants, Inc., 2003).

Figure 8-5. Taylor Creek Stormwater Treatment Area (STA) (photo by the SFWMD).

The Nubbin Slough STA is the larger of the two pilot STAs being implemented north of the lake. It is located approximately 6.5 miles southeast of the City of Okeechobee, adjacent to Nubbin Slough, immediately north of State Road 710 and just east of the bridge that spans Nubbin Slough. This two-celled STA is approximately 809 ac with an effective treatment area of 773 ac. The projected long-term average TP reduction within the STA was estimated to be 5 metric tons per year (mt/yr) or about 85 percent of the TP load of Nubbin Slough at the project location (Stanley Consultants, Inc., 2003).

Construction of the Nubbin Slough STA was completed in September 2006. However, due to a series of mechanical problems uncovered during pump tests and, later, with the aggradations of sediment in the pump basin, the Nubbin Slough STA could not be operated as designed. In April 2012, construction modifications to the Nubbin Slough STA intake basin were initiated as a joint effort between the USACE and District. Refinements were made to maintain the stability of Nubbin Slough embankments within the pump station storage pool, increase pump basin volume, and minimize sediment transport into the S-385 pump station intake basin. Construction of the pump station intake basin modifications was completed in July 2012. Interim operation and monitoring will be initiated when there is sufficient water in Nubbin Slough to do so. The District is slated to take over this project from the USACE by the end of September 2012.

HYBRID WETLAND TREATMENT TECHNOLOGY

This technology combines the strength of both wetland and chemical treatments to maximize P removal, minimize chemical use, and facilitate the removal of nitrogen (N) species. Chemical coagulants are added, either continuously or intermittently, to the front end of the treatment system, which contains one or more deep zones to capture the resulting floc material. A fundamental concept of HWTT is that the floc resulting from coagulant addition generally remains active and has the capability of additional P sorption. Both passive and active reuse of floc material is practiced in HWTT. Passive reuse refers to the settling of active flocs on plant roots and stems, where it can contact additional untreated parcels of water. Active reuse refers to the mechanical resuspension of previously settled floc. In addition to passive and active recycling/reuse of chemical flocs, optimization approaches include the sequencing and configuring of the wetland unit processes to provide desirable N and P species transformations.

There are currently six operational HWTT systems in the Northern Everglades. Four HWTT systems were constructed during WY2008 and operational optimization efforts were subsequently initiated. Three of the HWTT facilities — the 0.7-ac Ideal 2 Grove system, the 1.7-ac Nubbin Slough system, and the 1.4-ac Mosquito Creek system — are continuous flow systems (subject to water flow availability), while the fourth is situated adjacent to a dairy lagoon and is used for batch treatment of high strength waters. The dairy lagoon system was discontinued at the end of WY2009 as adequate data had been obtained. Two HWTT facilities, Lemkin Creek and Wolff Ditch, were constructed and brought online during WY2010. A HWTT facility expansion from 10 to 20 cfs was completed at Grassy Island in the Taylor Creek Basin at the beginning of WY2012, with modifications expected to be completed by WY2013. Effective performance of the HWTT technology is demonstrated by the reduction in TP concentrations between the inflow and outflow during the entire study period (Watershed Technologies, LLC, 2012). Flow-weighted mean TP concentration reductions of the six active HWTT facilities during the entire study period ranged from 66 to 88 percent (**Figure 8-6**).

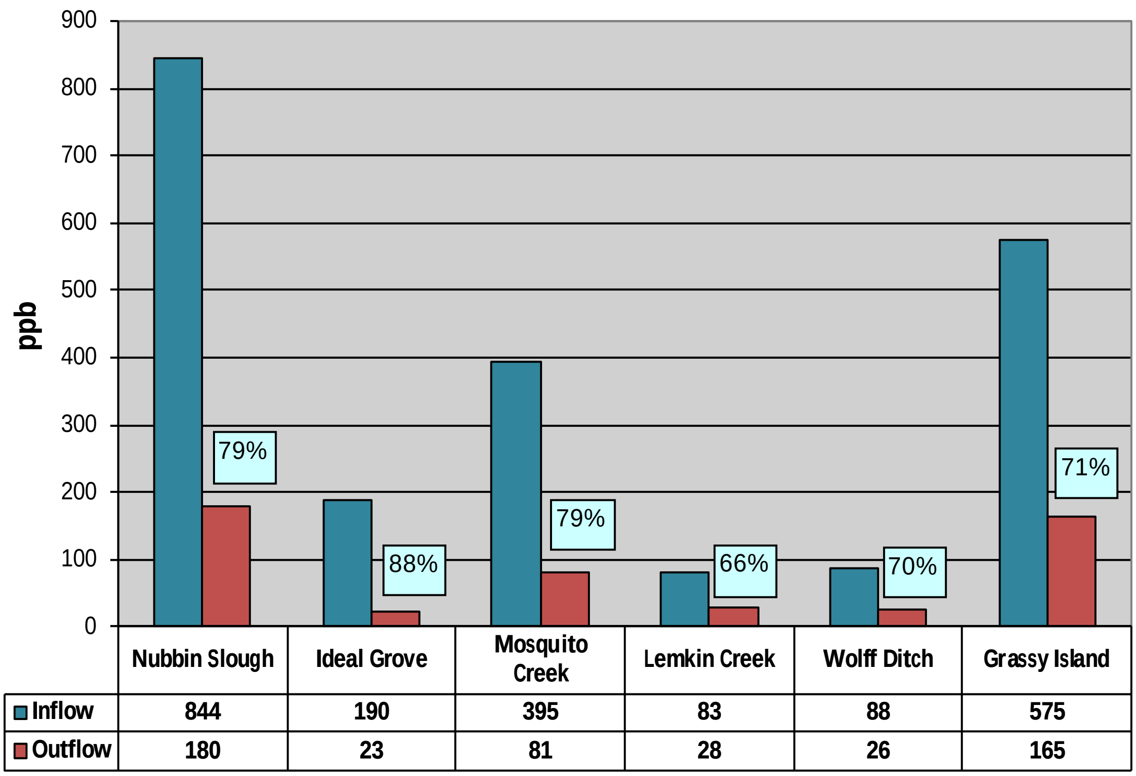
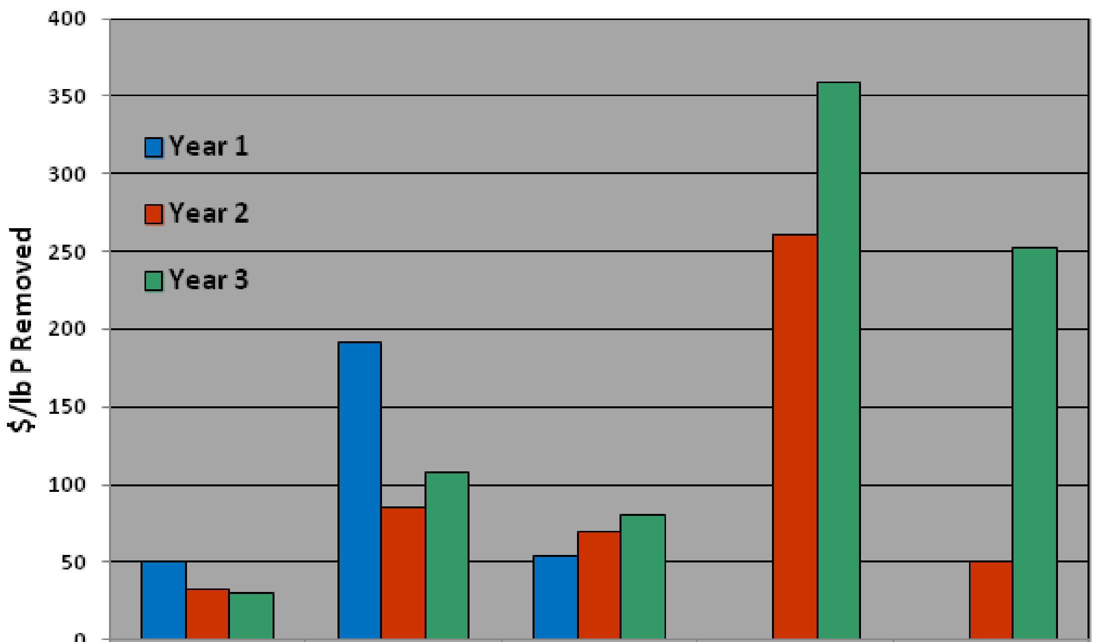


Figure 8-6. Flow-weighted TP concentrations in parts per billion (ppb). The period of record for TP concentrations is November 21, 2008–September 30, 2011 for Nubbin Slough, Ideal Grove, and Mosquito Creek; March 9, 2010–September 30, 2011 for Lemkin Creek and Wolff Ditch; and July 11, 2011–November 12, 2011 for Grassy Island.

Several conditions such as flow availability, inflow P availability for treatment, and inflow water quality parameters have proven to be vital in maximizing the cost-benefit of specific projects. Site selection therefore becomes a key component of maximizing productivity and efficiency. Some of the HWTT locations were chosen to accomplish important goals not directly related to maximum P removal, but nonetheless they have a direct impact on the cost-benefit of each facility. The cost-benefit calculations for the five active HWTT facilities with more than one year of full operation were done using the Full Capacity and the Present Value methods (Watershed Technologies, LLC, 2012). Comparative cost-benefit calculations (in dollars per pound of TP removed) for the current period (Year 3) ranged from $30 at Nubbin Slough to $359 at Lemkin Creek (**Figure 8-7**). Changes in cost-benefit calculations are a function of several variables, with the most relevant being cost, flow, capacity utilization, P removal, and site conditions. It is important to mention that one of the basic assumptions in calculating cost-benefit values was the exclusion of land cost because it was either provided by the willing participation of a land owner or was situated on District-owned land. Low cost-benefit values at Nubbin Slough are a combination of high inflow TP concentration (792 ppb) and high TP removal (86 percent). In contrast, high cost-benefit values at Lemkin Creek and Wolff Ditch are primarily due to low TP concentrations (76 ppb and 44 ppb, respectively). However, in addition to P removal, HWTT systems provide environmental benefits through wetland and wildlife habitat restoration and creation, as is the case for the Lemkin Creek and Wolff Ditch systems.



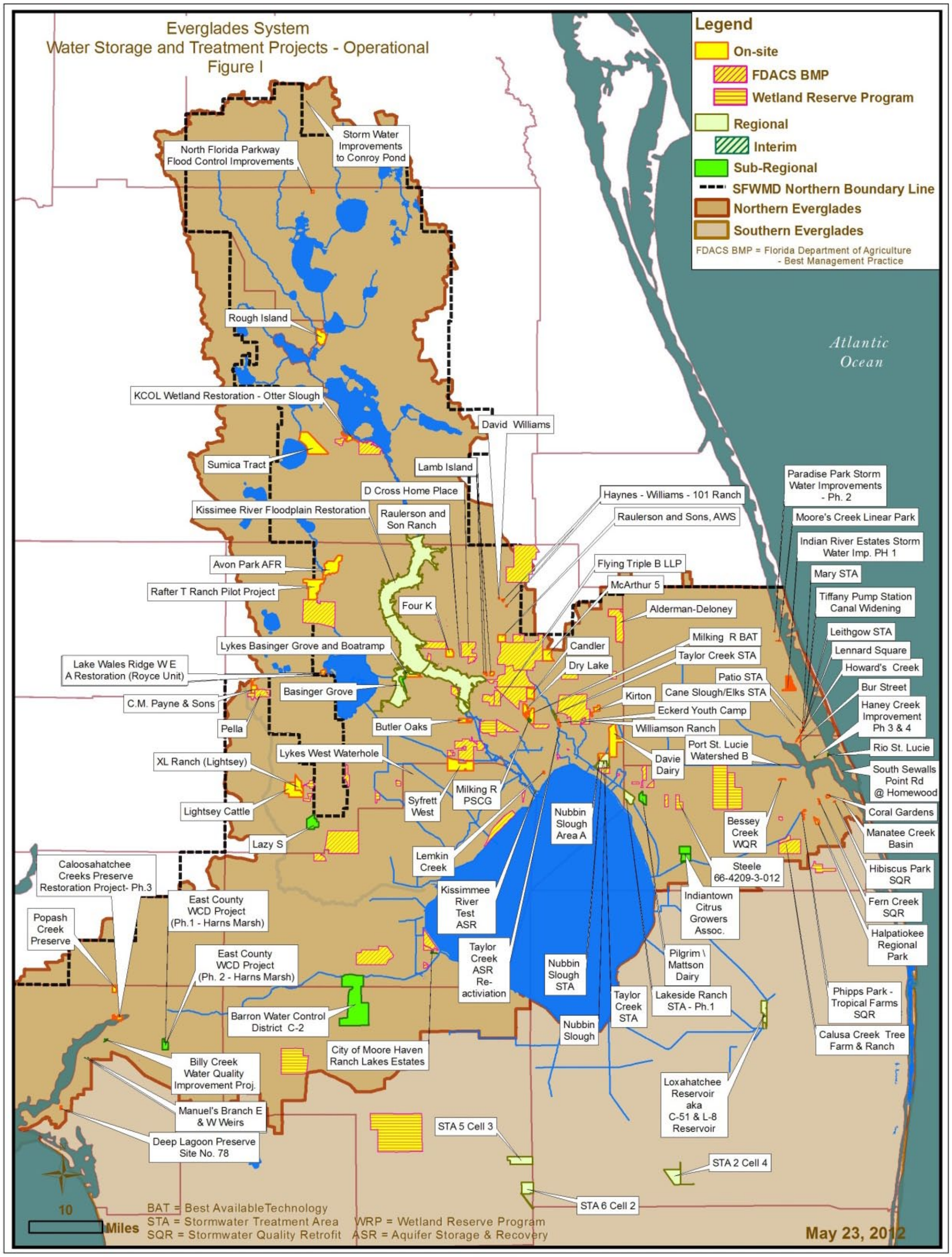
	Nubbin Slough	Ideal Grove	Mosquito Creek	Lemkin Creek	Wolff Ditch
Year 1	51	191	54		
Year 2	33	85	69	261	51
Year 3	30	108	80	359	252

Figure 8-7. Comparative cost-benefit values using the Full Capacity and Present Value methods for years one to three. [Note: $/lb – money per pound.]

DISPERSED WATER MANAGEMENT

The Lake Okeechobee Watershed restoration efforts are not only in the form of large-scale publicly-owned and operated projects, but also include both public and private landowners participating in a variety of efforts that spread excess water across the landscape and distribute it at shallow depths. These smaller-scale projects optimize the use of existing facilities and require little new construction to retain significant cumulative volumes of water. Low installation and maintenance costs associated with water retention and nutrient reduction projects make them a cost-effective complement to the larger regional storage and treatment projects. A total of 138,016 acre-feet (ac-ft) of water have been stored on 228,723 ac since October 2005, most of which is in the Northern Everglades, through a combination of dispersed water management, sub-regional, and regional projects (**Figure 8-8**). Landowners typically have participated in dispersed water management program under three types of approaches.

The Florida Ranchlands Environmental Services Project was the pilot effort for the Northern Everglades – Payment for Environmental Services (NE-PES) program. The District released the NE-PES solicitation last year in collaboration with the FDACS, FDEP, University of Florida's Institute for Food and Agricultural Sciences (UF/IFAS), United States Department of Agriculture National Resources Conservation Service (USDA-NRCS), MacArthur Agro-ecology Research Center, and World Wildlife Fund. The second solicitation of the NE-PES program was released in September 2012. These two other approaches involve cost-sharing or easements acquired primarily by the USDA-NRCS. Once a landowner has successfully participated in one type of program, there is often willingness to participate in other, longer-term programs with the potential to retain more water and reduce nutrients in even larger amounts.



530 **Figure 8-8.** Locations of the dispersed water management, sub-regional,
531 and regional projects in the Northern Everglades Protection Area.

FEASIBILITY STUDIES AT THE SUB-WATERSHED LEVEL

Lake Okeechobee Pre-drainage Characterization

The Lake Okeechobee Protection Plan recommends that feasibility studies be conducted at the sub-watershed level. There are six sub-watersheds that drain by gravity towards Lake Okeechobee: Fisheating Creek, Indian Prairie, Lake Istokpoga, Upper and Lower Kissimmee, and Taylor Creek\Nubbin Slough. The Fisheating Creek Sub-watershed was the first sub-watershed feasibility study initiated. During the course of the Fisheating Creek Feasibility Study, it was decided that a comprehensive study establishing preliminary planning targets for all the remaining sub-watersheds be conducted before proceeding with other sub-watershed studies. This led to the Lake Okeechobee Pre-drainage Characterization Project the goal of which is to establish these preliminary planning targets intended to serve as guidelines for each of the remaining sub-watershed feasibility studies.

The Lake Okeechobee Pre-drainage Characterization Project uses the Watershed Assessment Model (WAM) (SWET, 2011a, 2011b) to compare existing hydrological conditions with historical conditions that existed before significant human influences took place (i.e., pre-drainage 1850s). Currently, output from the WAM existing conditions run is being analyzed. Pertinent literature describing pre-drainage conditions was reviewed and relevant data incorporated into WAM in preparation for the pre-drainage condition model runs.

Fisheating Creek Feasibility Study

Fisheating Creek is the only tributary with an uncontrolled discharge point to the lake (i.e., there are no structures on Fisheating Creek directly controlling discharge to the lake). It is characterized by extremely flashy flows and is one of the major sources of TP loading to Lake Okeechobee (SFWMD et al., 2011). The Fisheating Creek Feasibility Study involves formulation, evaluation, and selection of the most appropriate mix of storage and water quality features to improve hydrology and water quality in the Fisheating Creek Sub-watershed. Planning targets for achieving surface water storage and quality improvements (P-load reduction) were also established through analyzing pre-drainage and existing conditions outputs from WAM simulations in close coordination with stakeholders and other agencies. The next step is to locate conceptual water quality and storage features. A significant portion of the hydrography (18 percent of the sub-watershed total area) located north of State Road 70 will be modified under the USDA-NRCS's Wetland Reserve Program. Details of the proposed modifications that are currently under development will significantly impact the WAM inputs for this study. Therefore, the coordinating agencies have determined that the best interest of the public is served by postponing completion of the study until the necessary data related to the benefits achieved under the Wetland Reserve Program are available. The USDA-NRCS plans to have the necessary data available in 2013 and the District plans on resuming the project once this information is available.

Taylor Creek Site Feasibility Study

The objective of the Taylor Creek Site Feasibility Study is to evaluate alternatives and develop a preferred plan for water quality and storage options for the District's Taylor Creek/Grassy Island property located in the Taylor Creek/Nubbin Slough Sub-watershed. The District owns approximately 5,000 acres of a former ranch that is ideally located in close proximity to Taylor Creek where water quality treatment and storage facilities can be constructed. Staff at the District has evaluated prior studies and reports that were conducted for this site under various programs with the goal of providing water quality treatment and storage on the site. In FY2013, the District is planning to conduct hydrological modeling for several options in order to quantify the potential benefits and associated costs.

WATERSHED ASSESSMENT, MONITORING AND RESEARCH

WATER QUALITY MONITORING IN THE WATERSHED

To achieve the NEEPP required monitoring, the District monitors the water quality of inflows to and outflows from Lake Okeechobee at District-operated control structures and maintains a long-term water quality monitoring network within the Lake Okeechobee Watershed (**Figure 8-9**). This network is continuously reviewed for efficiency and to ensure all data objectives associated with legislatively mandated and permit required monitoring are being met. This enables taxpayers to be kept informed about the progress of state and federally funded restoration efforts. In addition, the District coordinates monitoring efforts with the FDACS, FDEP, and United States Geological Survey (USGS) to leverage monitoring sites and reduce duplication of efforts.

The District's current monitoring network involves collection of data from three hydrologic levels within the Lake Okeechobee Watershed through the use of several project-level initiatives. Monitoring is conducted at loading stations at the sub-watershed and drainage basin level (basin loading stations) within the sub-watersheds for flow, TP, total nitrogen (TN), and other parameters at 35 control structures discharging directly into Lake Okeechobee as mandated by the Lake Okeechobee Operating Permit issued by the FDEP. Sub-basin-level monitoring is conducted at ambient monitoring stations and tributary loading stations under three different projects: the ambient long-term trend projects, which are the Kissimmee River Eutrophication Abatement (KREA) and Taylor Creek Nubbins Slough (TCNS), the USGS sub-basin loading project (OKUSGS), and the Lake Okeechobee Watershed Assessment (LOWA). Project-specific, parcel- or farm-level monitoring (dairy monitoring stations) is also conducted. Data from these monitoring efforts reside in the District's hydrometeorologic database, DBHYDRO, and are associated with the project names listed above in parentheses.

Total Phosphorus and Total Nitrogen Loads to Lake Okeechobee

TP loading rates into Lake Okeechobee have varied over time as a result of a combination of climatic conditions, land use changes, and changes in water management conditions. From WY1981–WY2012, the highest TP loading rate was 1,189 mt in WY1983, followed by 960 mt in WY2005, and 913 mt in WY1998 (**Table 8-1**). The highest five-year average load was 715 mt during the WY2002–WY2006 period of record (mainly due to the high discharges to the lake during the 2004 and 2005 hurricanes). The most recent five-year average load was 387 mt (WY2008–WY2012), which exceed the TMDL by 247 mt and was a ten percent increase from 352 mt during the previous five-year period (WY2007 to WY2011). This increase was a result of the increased load in WY2012 that was primarily caused by an October 2011 storm event. This October event produced 47 percent of the total flow of the year and 48 percent of the TP surface load (see Chapter 9 of this volume). The five-year average from WY2007 to WY2011 is the lowest average value since 1981 because it includes three of the driest years (WY2007, WY2008, and WY2011) since 1981. These extremes confirm the rationale for the TMDL being based on a five-year average that can account for large variations in water flow and related nutrient loads.

The WY2012 TN load was estimated at 4,620 mt, an increase of 1,707 mt (59 percent) compared to the WY2011 load (**Table 8-2**). The WY2008–WY2012 TN load averaged 4,788 mt/yr, a seven percent increase from the WY2007–WY2011 average of 4,457 mt/yr. As with TP load, this increase resulted from the October 2011 storm event that contributed 42 percent of the TN surface load in this past water year. There is no in-lake goal for TN.

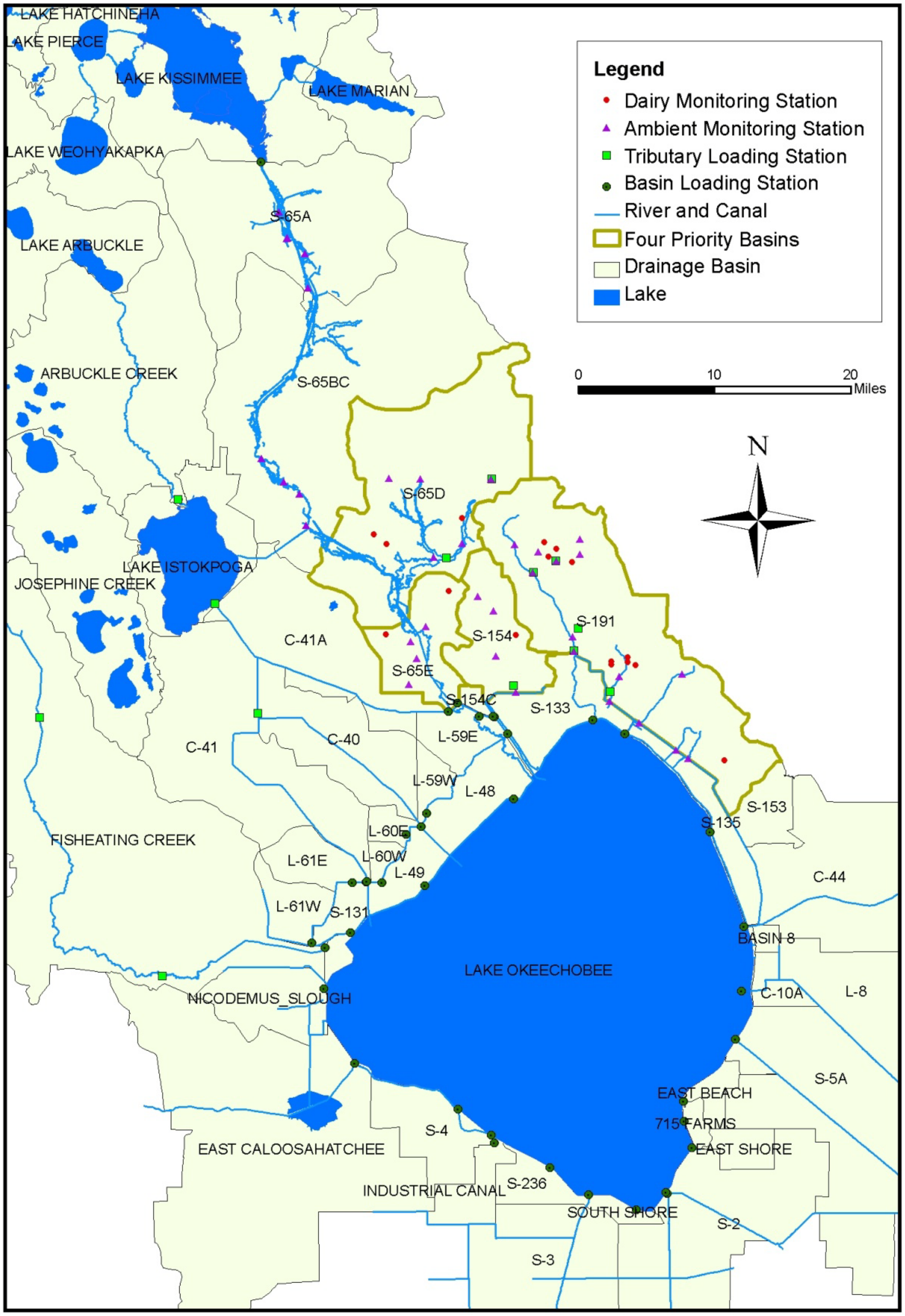


Figure 8-9. Locations of Water Year 2012 (WY2012) (May 1, 2011–April 30, 2012) water quality sampling stations under the ambient, tributary and basin loading projects in the Lake Okeechobee Watershed.

627 **Table 8-1.** Annual total phosphorus (TP) loads to Lake Okeechobee
628 from both controllable and uncontrollable sources from WY1981–WY2012.
629 [Note: NA – not available]

Water Year (May–April)	Measured Load[a] (mt)	Long-Term Load (Five-Year Moving Average)[a] (mt)	Long-Term Over-Target Load (Five-Year Moving Average)[a,b] (mt)
1981	151	NA	NA
1982	440	NA	NA
1983	1,189	NA	NA
1984	369	NA	NA
1985	500	530	390
1986	421	584	444
1987	562	608	468
1988	488	468	328
1989	229	440	300
1990	365	413	273
1991	401	409	269
1992	408	378	238
1993	519	384	244
1994	180	375	235
1995	617	425	285
1996	644	474	334
1997	167	425	285
1998	913	504	364
1999	312	531	391
2000	685	544	404
2001	134	442	302
2002	624	534	394
2003	639	479	339
2004	553	527	387
2005	960	582	442
2006	795	714	574
2007	203	630	490
2008	246	551	411
2009	656	572	432
2010	478	476	336
2011	177	352	212
2012	377	387	247

630 [a] Includes an atmospheric load of 35 mt per year based on the Lake Okeechobee Total Maximum Daily Load (TMDL)
631 (FDEP, 2001).
632 [b] Target is the Lake Okeechobee TMDL of 140 mt compared to a five-year moving average.
633

Table 8-2. Annual total nitrogen (TN) loads in metric tons (mt) to Lake Okeechobee from both controllable and uncontrollable sources from WY2000–WY2012 (May 1, 1999–April 30, 2012). [Note: NA – not available.]

Water Year (May–April)	Measured TN Load (mt)	Long-term TN Load (Five-Year Moving Average)[a] (mt)
2000	6,693	NA
2001	2,517	NA
2002	7,826	NA
2003	8,279	NA
2004	6,526	6,368
2005	8,775	6,785
2006	7,992	7,880
2007	2,965	6,907
2008	3,393	5,930
2009	6,689	5,963
2010	6,325	5,473
2011	2,913	4,457
2012	4,620	4,788

a. Includes an atmospheric load of 1,233 mt per year to account for atmospheric deposition

Total Phosphorus and Total Nitrogen Loading Data by Drainage Basin

Surface water flow and TP and TN loads to the lake for WY2012 were calculated for the major drainage basins using the basin loading stations. These calculations include discharges from Lakes Istokpoga and Kissimmee. These lakes are the outfalls of sub-watersheds that collect water flow and nutrient loads from smaller surrounding drainage basins (**Figure 8-9**). Data are based on monitoring stations where flow is continuously monitored and TP and TN samples are collected biweekly, based on flow, or monthly at a minimum. During WY2012, the TP load to the lake from all drainage basins and atmospheric deposition, which was estimated at 35 mt (FDEP, 2001) was 377 mt (**Table 8-3**).

The largest surface water inflow came from the Upper Kissimmee Sub-watershed (above structure S-65), followed by the Lower Kissimmee and Lake Istokpoga sub-watersheds. The Upper Kissimmee Sub-watershed covers about 30 percent of the drainage area in the Lake Okeechobee Watershed, and contributed about 42 percent of total inflow and 18 percent of total TP load during WY2012 (**Table 8-3**). The Lake Istokpoga Sub-watershed covers 11 percent of the drainage area in the Lake Okeechobee Watershed, and discharged 12 percent of the total inflow and five percent of the total TP load in WY2012. The Lower Kissimmee Sub-watershed comprises 12 percent of the drainage area in the Lake Okeechobee Watershed, and contributed about 17 percent of total inflow and 30 percent of total TP load during WY2012. The highest unit area load of TP came from the Industrial Canal Basin [1.48 pounds per acre (lb/ac); Southern Lake Okeechobee Sub-watershed], followed by Nicodemus Slough Basin (1.07 lb/ac; Fisheating Creek Sub-watershed), S-154C (0.66 lb/ac; Taylor Creek/Nubbin Slough Sub-watershed), and L-61E basin (0.61 lb/ac; Indian Prairie Sub-watershed) during WY2012. In terms of flow-weighted TP concentrations, the C-40 Basin had the highest value (930 ppb; Indian Prairie Sub-watershed), followed by the C-41 Basin (899 ppb; Indian Prairie Sub-watershed) and S-154 Basin (599 ppb; Taylor Creek/Nubbin Slough Sub-watershed) during WY2012.

During WY2012, TN load to the lake from all drainage basins and atmospheric deposition (estimated as 1,233 mt) (James et al., 2005) was 4,620 mt (**Table 8-4**). The highest TN load came from the Upper Kissimmee Sub-watershed, followed by the Lower Kissimmee Sub-watershed and the Lake Istokpoga Sub-watershed. The highest unit area load came from the Nicodemus Slough Basin (13.52 lb/ac; Fisheating Creek Sub-watershed), followed by the Industrial Canal Basin (12.58 lb/ac; Southern Lake Okeechobee Sub-watershed), and L-61E basin (6.50 lb/ac; Indian Prairie Sub-watershed). In terms of flow-weighted TN concentration, the S-2 Basin had the highest value [3.59 parts per million (ppm); Southern Lake Okeechobee Sub-watershed], followed by the C-40 and C41 basins (3.01 and 2.90 ppm respectively; Indian Prairie Sub-watershed).

Table 8-3. WY2012 surface water inflows in acre-feet (ac-ft), TP loads in mt and concentrations in parts per billion (ppb), and unit load in pounds per acre (lb/ac) from the drainage basins in the Lake Okeechobee Watershed.

Source	Area		Discharge		TP Load		Unit Load	Average TP Concentration
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppb)
715 Farms (Culvert 12A)	3,302	0.1	0	0	0.0	0	0.00	no flow
C-40 Basin (S-72) – S-68	43,965	1.3	3,691	0.2	4.2	1.2	0.21	929
C-41 Basin (S-71) – S-68	94,655	2.8	13,630	0.7	15.1	4.4	0.35	899
C-41A Basin (S-84) – S-68	58,488	1.7	22,438	1.2	8.1	2.4	0.31	294
C-44 Basin (S-308 at St. Lucie Canal)	129,430	3.8	49,689	2.6	10.4	3.0	0.18	170
East Beach Drainage District (Culvert 10)	6,624	0.2	0	0	0.0	0.0	0.00	no flow
East Shore Drainage District (Culvert 12)	8,416	0.2	0	0	0.0	0.0	0.00	no flow
Fisheating Creek at Lakeport	297,817	8.7	97,017	5.0	23.7	6.9	0.18	198
Industrial Canal	13,024	0.4	32,325	1.7	8.7	2.6	1.48	219
L-48 Basin (S-127 total)	20,774	0.6	4,093	0.2	0.8	0.2	0.09	164
L-49 Basin (S-129 total)	12,093	0.4	7,326	0.4	0.7	0.2	0.13	82
L-59E Basin (G-33+G-34)	14,409	0.4	0	0	0.0	0.0	0.00	61
L-59W Basin (G-74)	6,440	0.2	5,414	0.3	1.3	0.4	0.46	200
L-60E Basin (G-75)	5,038	0.1	1,618	0.1	0.3	0.1	0.13	157
L-60W Basin (G-76)	3,271	0.1	2,348	0.1	0.6	0.2	0.39	200
L-61E Basin	14,286	0.4	20,718	1.1	4.0	1.2	0.61	155
Taylor Creek/Nubbin Slough (S-191)	120,754	3.5	48,434	2.5	31.4	9.2	0.57	526
S-131 Basin	7,164	0.2	3,090	0.2	0.3	0.1	0.08	66
S-133 Basin	25,660	0.7	1,122	0.1	0.3	0.1	0.03	233
S-135 Basin	18,088	0.5	158	0.0	0.0	0.0	0.00	39
S-154 Basin	31,619	0.9	8,206	0.4	6.1	1.8	0.42	599
S-154C Basin	2,179	0.1	1,367	0.1	0.7	0.2	0.66	387
S-2 Basin	106,372	3.1	1,091	0.1	0.4	0.1	0.01	258
S-3 Basin	62,946	1.8	444	0.0	0.1	0.0	0.00	98
S-4 Basin	26,389	0.8	7,738	0.4	1.2	0.4	0.10	126
Lower Kissimmee Sub-watershed (S-65E–S-65)	425,196	12.4	333,378	17.1	101.3	29.6	0.52	246
South Florida Conservancy Drainage District (S-236)	11,028	0.3	0	0	0.0	0.0	0.00	no flow
South Shore/South Bay Drainage District (Culvert 4A)	4,134	0.1	0	0	0.0	0.0	0.00	no flow
Nicodemus Slough Basin (Culvert 5, 5A)	25,641	0.7	73,114	3.8	12.4	3.6	1.07	137
Upper Kissimmee Sub-watershed (S-65)	1,021,674	29.7	813,975	41.9	61.5	18.0	0.13	61
Lake Istokpoga Sub-watershed (S-68)	392,147	11.4	228,039	11.7	17.4	5.1	0.10	62
S-5A Basin (S-352 West Palm Beach Canal)	119,443	3.5	0	0	0.0	0.0	0.00	no flow
East Caloosahatchee Basin (S-77)	200,993	5.8	127,462	6.6	26.4	7.7	0.29	168
L-8 Basin (Culvert 10A)	108,402	3.1	36,619	1.9	5.0	1.5	0.10	112
Totals from Lake Okeechobee Watershed	**3,441,861**	**100.0**	1,944,545	**100**	**342**	**100**	**0.22**	**143**
Atmospheric Deposition					35			
Total Loads to Lake Okeechobee					**377**			

Table 8-4. WY2012 surface water inflows, and TN loads in mt and concentrations in parts per million (ppm) from the drainage basins in the Lake Okeechobee Watershed.

Source	Area		Discharge		TN Load		Unit Load	Average TN Concentration
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppm)
715 Farms (Culvert 12A)	3,302	0.1	0	0	0	0	0.00	no flow
C-40 Basin (S-72) – S-68	43,965	1.3	3,691	0.2	13.7	0.4	0.69	3.01
C-41 Basin (S-71) – S-68	94,655	2.8	13,630	0.7	48.7	1.4	1.13	2.90
C-41A Basin (S-84) – S-68	58,488	1.7	22,438	1.2	60.6	1.8	2.28	2.19
C-44 Basin (S-308 at St. Lucie Canal)	129,430	3.8	49,689	2.6	96.8	2.9	1.65	1.58
East Beach Drainage District (Culvert 10)	6,624	0.2	0	0	0.0	0.0	0.00	no flow
East Shore Drainage District (Culvert 12)	8,416	0.2	0	0	0.0	0.0	0.00	no flow
Fisheating Creek at Lakeport	297,817	8.7	97,017	5.0	224.2	6.6	1.66	1.87
Industrial Canal	13,024	0.4	32,325	1.7	74.3	2.2	12.58	1.86
L-48 Basin (S-127 total)	20,774	0.6	4,093	0.2	9.0	0.3	0.96	1.79
L-49 Basin (S-129 total)	12,093	0.4	7,326	0.4	14.4	0.4	2.63	1.60
L-59E Basin (G-33+G-34)	14,409	0.4	0	0.0	0.0	0.0	0.00	1.86
L-59W Basin (G-74)	6,440	0.2	5,414	0.3	11.0	0.3	3.77	1.65
L-60E Basin (G-75)	5,038	0.1	1,618	0.1	3.0	0.1	1.31	1.52
L-60W Basin (G-76)	3,271	0.1	2,348	0.1	4.5	0.1	3.03	1.56
L-61E Basin	14,286	0.4	20,718	1.1	42.1	1.2	6.50	1.65
Taylor Creek/Nubbin Slough (S-191)	120,754	3.5	48,434	2.5	114.5	3.4	2.09	1.92
S-131 Basin	7,164	0.2	3,090	0.2	5.8	0.2	1.78	1.51
S-133 Basin	25,660	0.7	1,122	0.1	2.4	0.1	0.21	1.72
S-135 Basin	18,088	0.5	158	0.0	0.3	0.0	0.04	1.54
S-154 Basin	31,619	0.9	8,206	0.4	21.5	0.6	1.50	2.13
S-154C Basin	2,179	0.1	1,367	0.1	2.8	0.1	2.83	1.67
S-2 Basin	106,372	3.1	1,091	0.1	4.8	0.1	0.10	3.59
S-3 Basin	62,946	1.8	444	0.0	1.5	0.0	0.05	2.65
S-4 Basin	26,389	0.8	7,738	0.4	21.0	0.6	1.75	2.20
Lower Kissimmee Sub-watershed (S-65E–S-65)	425,196	12.4	333,378	17.1	547.1	16.2	2.84	1.33
South Florida Conservancy Drainage District (S-236)	11,028	0.3	0	0	0.0	0.0	0.00	no flow
South Shore/South Bay Drainage District (Culvert 4A)	4,134	0.1	0	0	0.0	0.0	0.00	no flow
Nicodemus Slough Basin (Culvert 5, 5A)	25,641	0.7	73,114	3.8	157.2	4.6	13.52	1.74
Upper Kissimmee Sub-watershed (S-65)	1,021,674	29.7	813,975	41.9	1113.0	32.9	2.40	1.11
Lake Istokpoga Sub-watershed (S-68)	392,147	11.4	228,039	11.7	450.4	13.3	2.53	1.60
S-5A Basin (S-352 West Palm Beach Canal)	119,443	3.5	0	0	0.0	0.0	0.00	no flow
East Caloosahatchee Basin (S-77)	200,993	5.8	127,462	6.6	250.3	7.4	2.75	1.59
L-8 Basin (Culvert 10A)	108,402	3.1	36,619	1.9	92.0	2.7	1.87	2.04
Totals from Lake Okeechobee Watershed	**3,441,861**	**100.0**	**1,944,545**	**100**	**3,387**	**100**	**2.17**	**1.41**
Atmospheric Deposition					1,233			
Total Loads to Lake Okeechobee					**4,620**			

Ambient Water Quality Data Analysis

The long-term tributary or ambient water quality stations under projects KREA and TCNS consist of river and basin-level monitoring locations that are sampled on a biweekly flow-only basis. This analysis considered both the ambient and tributary loading stations (**Figure 8-9**). It is also important to note that the tributary loading stations for C-41 and C-41A are well upstream compared to the basin loading stations. TP and TN concentrations are collected at these 42 monitoring stations. The ambient water quality network has primarily focused on the assessment of those basins considered critical to the nutrient concentration issues in the Lake Okeechobee Watershed (**Figure 8-9**). Additional water quality assessment in the watershed is done under the LOWA monitoring network. These monitoring sites are a part of the Lake Okeechobee Watershed Regulatory Phosphorus Source Control Program and the results of these efforts are discussed in Chapter 4 of this volume. The statistical summaries given in **Tables 8-8** and **8-9** in the *Preliminary Results of the Tributary Trend Analysis* section also include concentration data from sites established for the Lake Okeechobee Tributary Loadings project. This project was formally run by the USGS under contract from the District, FDACS, and USACE. These sites collect grab and automatic samples, with some site's samplers programmed to collect on flow and others that collect on time. The water quality data for these sites would ideally be matched with the flow data collected at these sites, in order to establish real-time loadings in the tributaries to Lake Okeechobee. Nutrient concentration samples collected at these sites were collected during periods of flow and non-flow. This could result in higher or lower values than calculations made with concentration data collected only during periods of observed flow. The use of data from these sites will be reevaluated in WY2013 and may be reported only as loads in the future.

The basic statistics for WY2012 TP concentration data by basin from the 42 ambient sites are presented in **Table 8-5**. For comparison purpose, data from WY2011 and the five-year averages for WY2006–WY2010 are also included. Due to its size and the numbers of monitoring stations, the S-191 Basin (Taylor Creek/Nubbin Slough) is further divided into two sub-basins: Taylor Creek (S-191TC) and Nubbin Slough (S-191NS). During WY2012, the highest median TP concentration was in the S-154 Basin (899 ppb), followed by the S-191TC (395 ppb) and S-65D (368 ppb) basins. The median TP concentrations from the S-154 Basin also displayed the highest increase when compared with data collected in WY2011. All S-154 upper tributary sites had high concentration values during the WY2012 wet season. Most of the high concentrations were in September, October, and November 2011. The first concentrations for this water year were collected after an entire year of no observed flows at these sites. This indicates that the legacy P issues that are well documented for this watershed continue to persist and the first few flushes after extended periods with no flow still consistently exhibit very high TP concentrations. Many of the higher concentration data points observed for WY2012 in the S-154 Basin were also collected during the hydrologic timeframe of the October 2011 storm. This pattern of elevated concentrations after long periods of no flow was also observed at the LOWA sampling locations within this basin (see Chapter 4).

TN values are calculated using both nitrate + nitrite (NO_x) and total Kjeldahl nitrogen (TKN) concentrations, though the majority of TN comes from the organic form of N (TKN). In terms of median TN concentrations, the S-154 Basin had the highest value [2.37 parts per million (ppm)], followed by Fisheating Creek (2.10 ppm), S-191NS (2.08 ppm), and S-191TC (2.03 ppm) basins (**Table 8-6**). Several, very high concentrations of TN were detected, but because these were paired with elevated levels of TP during times of increased flow, the values were deemed to be reasonable for the drainage areas and, therefore, included in the calculations. Review of the TN data for all the basins indicates a general consistency in concentration over the past six years.

Table 8-5. Statistics of TP data collected from the ambient network in the Lake Okeechobee Watershed. WY2012 and WY2011 values are included to show annual changes.

BASIN	WY2006 to WY2010 (TP)			WY2011 (TP)			WY2012 (TP)		
	Mean (ppb)	Median (ppb)	Number of	Mean (ppb)	Median (ppb)	Number of	Mean (ppb)	Median (ppb)	Number of
C-41	242	160	135	502	323	25	228	159	20
C-41A	82	79	143	46	41	37	63	60	74
Fisheating Creek	243	199	318	242	184	44	187	168	31
Lake Istokpoga	104	80	171	109	92	40	122	103	75
S-65A	77	68	235	65	59	48	77	66	47
S-65BC	92	77	223	63	58	48	68	60	52
S-65D	217	160	567	325	296	136	434	368	85
S-65E	424	253	141	281	167	28	298	167	32
S-154	552	426	201	538	483	31	978	899	14
S191TC (Taylor Creek)	411	319	1033	472	411	143	441	395	130
S-191NS (Nubbin Slough)	402	385	457	332	287	48	382	339	60

Table 8-6. Statistics of TN data collected from the ambient network in the Lake Okeechobee Watershed. WY2012 and WY2011 values are included to show annual changes.

BASIN	WY2006 to 2010 (TN)			WY2011 (TN)			WY2012 (TN)		
	Mean (ppm)	Median (ppm)	Number of Samples	Mean (ppm)	Median (ppm)	Number of Samples	Mean (ppm)	Median (ppm)	Number of Samples
C-41	2.29	1.96	139	2.56	2.12	25	1.98	1.71	20
C-41A	1.70	1.77	137	1.35	1.31	39	1.57	1.55	47
Fisheating Creek	2.47	2.06	288	2.16	1.95	43	2.08	2.10	31
Lake Istokpoga	1.46	1.46	168	1.32	1.30	40	1.34	1.37	47
S-65A	1.34	1.24	232	1.26	1.30	48	1.43	1.29	47
S-65BC	1.34	1.24	223	1.17	1.12	48	1.20	1.17	52
S-65D	1.66	1.59	538	1.60	1.53	137	1.70	1.73	85
S-65E	2.22	2.09	145	2.12	1.93	27	1.70	1.64	32
S-154	2.21	2.19	196	2.41	2.17	31	2.72	2.34	14
S-191TC (Taylor Creek)	2.06	1.82	985	1.97	1.77	143	2.05	2.03	129
S-191NS (Nubbin Slough)	2.25	2.07	439	1.65	1.67	47	2.15	2.08	60

RESEARCH AND ASSESSMENT

The District, in cooperation with the FDACS, FDEP, UF/IFAS, and other agencies and interested parties, has implemented a comprehensive research and assessment program for the Lake Okeechobee Watershed. Research and assessment projects are assessed and prioritized each year by an interagency team to ensure key issues and information needs are being addressed. The Northern Everglades Interagency Team now includes participants from local governments in the Northern Everglades Planning Area, including the Upper Kissimmee Basin and the Caloosahatchee and St. Lucie river watersheds. The work of this group is an integral component of the overall restoration program.

Six research, demonstration, and assessment projects were under way or completed in WY2012 (**Table 8-7**). Two of these projects (one completed and two ongoing) are highlighted in detail in this section. More information on the other projects may be found on the District's website at www.sfwmd.gov/okeechobee.

Table 8-7. Status of Lake Okeechobee Watershed research, demonstration, and assessment projects during WY2012.

Project Name (Investigator)	Major Objectives and Results	Status
Tributary Water Quality Analysis [South Florida Water Management District (SFWMD)]	The water quality trend assessment in the Lake Okeechobee watershed is under way to evaluate the effectiveness of Best Management Practices (BMP) and other phosphorus (P) reduction projects on reducing TP concentrations. The initial results for the work completed to date follow this table.	Underway
Baseline Soil Characterization of the Lakeside Ranch Stormwater Treatment Area (STA) – Phase 1 (SFWMD)	A baseline soil characterization of the Lakeside Ranch STA – Phase 1 was conducted to document the existing soil conditions in the STA following construction but prior to operation. Soil samples were taken from 91 locations within the 919-acre treatment area of the north STA at depth increments of 0–10 and 10–30 centimeters (cm), and analyzed for various physical and chemical constituents. The samples consisted of almost exclusively sandy soils. Often these fine sands were white and occasionally stratified with grey to brown layers showing a slight accumulation of organic matter. P concentrations across the STA were generally very low, averaging 30 and 21 milligrams per kilogram in the 0–10 and 10–30 cm depths, respectively. Water-soluble and Mehlich-extractable P (the labile pools of P) accounted for 2.3 and 14 percent of the total P, respectively. Sequential fractionation of total P yielded an inorganic to organic P ratio of 1:1.7. Total P currently stored in the top 30 cm of the soils ranged from 0.8 to 105 grams per square meter (g/m^2) (mean value = 4.40 g/m^2). Using single point isotherm, the soils demonstrated capability to retain an average of 16 g/m^2 of added P. While this number seemed low, the long-term function of the STA depends not only on the soil's initial P sorption capacity but also on the accretion of organic and other particulate matter in the STA over time. This project was completed in April 2012.	Complete
Hybrid Wetland Treatment Technology (HWTT) (Watershed Technologies, LLC, under contract to SFWMD and other state agencies)	This project involves the design, deployment, and monitoring of HWTT facilities in the St. Lucie River and Lake Okeechobee watersheds. The HWTT technology combines attributes of treatment wetlands and chemical treatment systems. Six HWTT facilities are currently operational. One facility is going through an expansion modification from the original 10 cubic feet per second (cfs) to 20 cfs flow capacity, with an expected completion by the beginning of WY2013. These systems show promising results with TP flow-weighted mean concentration reductions ranging from 66 to 88 percent.	Ongoing
Watershed Assessment Model (WAM) Applications in the Lake Kissimmee Sub-watershed (SFWMD)	The overall goal of this project is to apply the WAM to the Lake Kissimmee Sub-watershed to identify the hydrologic and water quality data needed to develop a nutrient budget for the Upper Chain of Lakes. WAM can be used to evaluate various P control programs to maximize water quality improvements from a drainage area. Specific objectives are to (1) update WAM input datasets with the latest rainfall data and P control efforts, (2) identify nutrient loading data needed for the lake nutrient budget analysis, and (3) calibrate WAM for the Lake Kissimmee Sub-watershed using available monitoring data. The project is scheduled to be completed by June 2013.	Ongoing
New Alternative Treatment Technologies (NATA) (SFWMD)	This SFWMD initiative provides a forum to explore additional nutrient reduction technologies. Interested vendors are invited to demonstrate potential technologies for reducing nutrient loading in both water and sediments, and to help reduce loads in the Northern Everglades watersheds. Twelve technologies have been reviewed by the technical review team to date and five are currently being tested either in bench studies, or in situ. Several products use proprietary clay-like materials originating from Australia that bind N and P when dispersed in water bodies. Another vendor utilizes electro-coagulation (EC) technology that destabilizes dissolved or suspended contaminants in water with steel and aluminum blades and introducing an electrical current to drive the chemical reactions. EC may also be capable of removing other constituents. Testing locations are site specific depending on the existing water chemistry and contingent on finding cooperative land owners or appropriate District-owned properties, as well as lake systems. The District is cooperating with both Palm Beach and Highlands counties to test two of the products.	Ongoing

Table 8-7. Continued.

Project Name (Investigator)	Major Objectives and Results	Status
Permeable Reactive Barrier (PRB) Technology [University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS)]	PRBs are a proven technique for groundwater remediation. Water treatment residuals (WTRs) are attractive for use in environmental P remediation because of their low to no cost. Materials selected for PRB construction should have high affinity for P, long-term stability, and appropriate hydraulic characteristics to enable adequate water flow. For this project, aluminum WTRs were tested since they are not influenced by redox conditions and P can be stably retained at a pH range of 4 to 7, which is common for most agricultural land soils . The main objectives of this project were to (1) assess the feasibility of significantly reducing P loads using PRB technology; (2) test suitable materials for PRB construction and design in the laboratory; and (3) install a pilot-scale PRB in the Lake Okeechobee Basin. Amendments that were evaluated included WTRs from six different water treatment facilities across South Florida. The feasibility study was completed in December 2009. The PRB design and laboratory testing of the different WTRs for PRB construction was completed in September 2010. The laboratory testing identified two aluminum WTRs with the desired physical and chemical properties for field testing. However, due to material availability and P sorption capacity, an aluminum WTR from the Manatee County facility was tested in this pilot study. In April 2011, two buried-wall PRBs were installed at Candler Ranch in Okeechobee basin. The previous land use at this site was a high intensive area containing a former dairy that took part in the District buyout program in 1987. Monitoring results from the Candler Ranch experimental site were completed in January 2012, and indicated that the PRB may be functioning chemically as designed, but the site was not suited hydrologically for PRB implementation**.** A second more suitable site has been identified to better evaluate the effectiveness of this technology where the PRB will be located immediately adjacent to the water conveyance system. Installation at this site was completed in August 2012, and monitoring will continue into Fiscal Year 2013 (October 1, 2012–September 30, 2013).	Ongoing

Preliminary Results of the Tributary Trend Analysis

The District is undertaking a water quality trend analysis that it anticipates including in the next Lake Okeechobee Protection Plan Update. Preliminary data on the work done so far on this effort is presented in this section. To date, four additional years of data were added to an early study by Zhang et al. (2011) and a Mann-Whitney test (a nonparametric equivalent of the two-sample t test) was used to determine if statistically significant differences existed between the two study periods: the baseline period from 1991 to 2001 and the period of LOPA-mandated BMP implementation from 2002 to 2011. The data were analyzed by station and basin at the 35 long-term water quality monitoring sites and 16 dairy sites located in the Northern Lake Okeechobee Sub-watershed (**Figure 8-9**). The 35 long-term, ambient monitoring stations included 27 stations in the four priority basins (S-191, S-154, S-65E, and S-65D) and eight along the Kissimmee River within the S-65A and S-65BC basins. The S-191 Basin (Taylor Creek/Nubbin Slough) is further divided into two sub-basins: Taylor Creek (S-191TC) and Nubbin Slough (S-191NS). Only TP data were collected at the 16 dairy stations.

Summary statistics included the number of samples, means, medians, minima, maxima, and standard deviations for each station (**Tables 8-8**, **8-9**, and **8-10**). Monthly mean concentrations were used for all other statistical analyses. Notched box-and-whisker plots summarize selected statistical properties of the datasets for each study period (**Figures 8-10** and **8-11**). Mann-Whitney tests were used to test for statistical significance between datasets at roughly a 95 percent confidence interval and to detect changes in constituent concentration variability over time (**Tables 8-8**, **8-9**, and **8-10**). These plots consist of the median, the lower quartile (25th percentile), the upper quartile (75th percentile), the smallest, and the largest values in the distribution of each dataset. The narrowest point of the notch represents the median of the data.

Table 8-8. Summary of TP concentrations collected at during the baseline period of 1991–2001 and Best Management Plan (BMP) implementation period of 2002–2011.

Basin	Station	Summary Statistics for Period from 1991 to 2001						Summary Statistics for Period from 2002 to 2011						Mann-Whitney p-value	Higher Period
		No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum	No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum		
S-65A	***KREA 79***	***68***	***0.050***	***0.032***	***0.017***	***0.043***	***0.228***	***117***	***0.071***	***0.033***	***0.023***	***0.065***	***0.228***	***<0.001***	***P2***
	KREA 91	***53***	***0.054***	***0.030***	***0.018***	***0.043***	***0.139***	***106***	***0.066***	***0.028***	***0.026***	***0.060***	***0.166***	***0.002***	***P2***
	KREA 92	63	0.066	0.034	0.026	0.057	0.206	117	0.056	0.023	0.023	0.049	0.148	0.068	P1
	KREA 97	***52***	***0.073***	***0.031***	***0.025***	***0.069***	***0.185***	***97***	***0.113***	***0.059***	***0.035***	***0.100***	***0.368***	***<0.001***	***P2***
S-65BC	KREA 93	59	0.077	0.039	0.018	0.071	0.213	115	0.082	0.038	0.031	0.072	0.272	0.283	P2
	KREA 94	54	0.108	0.099	0.029	0.085	0.641	115	0.083	0.040	0.031	0.073	0.273	0.149	P1
	KREA 95	63	0.078	0.057	0.015	0.061	0.309	115	0.066	0.047	0.022	0.057	0.453	0.256	P1
	KREA 98	***41***	***0.066***	***0.040***	***0.017***	***0.060***	***0.176***	***113***	***0.080***	***0.038***	***0.032***	***0.070***	***0.242***	***0.032***	***P2***
S-65D	***KREA 01***	***223***	***0.158***	***0.174***	***0.004***	***0.103***	***1.259***	***141***	***0.344***	***0.302***	***0.042***	***0.233***	***1.522***	***<0.001***	***P2***
	KREA 04	141	0.191	0.175	0.030	0.138	1.191	113	0.153	0.078	0.039	0.137	0.496	0.567	P1
	KREA 06A	***228***	***0.237***	***0.138***	***0.050***	***0.208***	***0.970***	***130***	***0.359***	***0.230***	***0.057***	***0.313***	***1.471***	***<0.001***	***P2***
	KREA 22	***114***	***0.069***	***0.113***	***0.010***	***0.041***	***1.032***	***144***	***0.074***	***0.055***	***0.022***	***0.060***	***0.447***	***<0.001***	***P2***
	KREA 23	***90***	***0.044***	***0.048***	***0.007***	***0.027***	***0.320***	***118***	***0.114***	***0.135***	***0.019***	***0.073***	***0.928***	***<0.001***	***P2***
S-65E	***KREA 14***	***123***	***0.537***	***0.328***	***0.096***	***0.487***	***1.946***	***81***	***0.372***	***0.279***	***0.023***	***0.302***	***1.210***	***<0.001***	***P1***
	KREA 17A	***182***	***0.242***	***0.211***	***0.026***	***0.167***	***1.155***	***144***	***0.327***	***0.230***	***0.032***	***0.254***	***1.388***	***<0.001***	***P2***
	KREA 19	392	0.581	0.760	0.035	0.219	4.005	131	0.546	0.478	0.038	0.419	2.050	0.087	P2
	KREA 41A	263	0.549	0.632	0.054	0.332	6.547	87	0.515	0.611	0.034	0.228	2.859	0.165	P1
S-154	***KREA 20***	***90***	***2.266***	***1.126***	***0.050***	***2.114***	***6.550***	***35***	***1.132***	***0.530***	***0.184***	***1.131***	***2.423***	***<0.001***	***P1***
	KREA 25	***85***	***1.337***	***0.881***	***0.185***	***1.010***	***4.145***	***44***	***0.631***	***0.408***	***0.060***	***0.616***	***1.652***	***<0.001***	***P1***
	KREA 28	***335***	***1.395***	***0.728***	***0.367***	***1.257***	***4.940***	***111***	***0.903***	***0.507***	***0.250***	***0.788***	***2.510***	***<0.001***	***P1***
	KREA 30A	***203***	***1.114***	***0.596***	***0.129***	***0.967***	***3.869***	***37***	***0.675***	***0.388***	***0.167***	***0.629***	***2.118***	***<0.001***	***P1***
S-191TC	TCNS 201	358	0.462	0.231	0.009	0.388	1.378	180	0.482	0.231	0.142	0.460	1.370	0.248	P2
	TCNS 204	412	0.922	0.549	0.108	0.702	2.779	232	0.802	0.350	0.352	0.696	2.000	0.362	P1
	TCNS 207	***736***	***0.677***	***0.758***	***0.081***	***0.438***	***5.834***	***298***	***0.848***	***0.427***	***0.199***	***0.728***	***2.258***	***<0.001***	***P2***
	TCNS 209	***708***	***0.532***	***0.482***	***0.040***	***0.381***	***3.422***	***248***	***0.413***	***0.310***	***0.043***	***0.327***	***1.610***	***<0.001***	***P1***
	TCNS 212	95	0.161	0.153	0.030	0.116	1.213	61	0.224	0.170	0.028	0.172	0.664	0.046	P2
	TCNS 213	718	0.486	0.296	0.039	0.417	1.725	388	0.433	0.222	0.085	0.371	1.237	0.076	P1
	TCNS 214	***732***	***0.242***	***0.115***	***0.054***	***0.218***	***1.034***	***378***	***0.290***	***0.134***	***0.081***	***0.266***	***0.939***	***<0.001***	***P2***
	TCNS 217	***362***	***0.380***	***0.302***	***0.030***	***0.296***	***1.893***	***208***	***0.310***	***0.245***	***0.023***	***0.243***	***1.520***	***0.026***	***P1***
S-191NS	***TCNS 220***	***181***	***0.615***	***0.289***	***0.236***	***0.543***	***1.788***	***109***	***0.519***	***0.417***	***0.054***	***0.428***	***2.860***	***<0.001***	***P1***
	TCNS 222	***682***	***0.579***	***0.230***	***0.079***	***0.537***	***1.458***	***292***	***0.461***	***0.217***	***0.091***	***0.427***	***1.580***	***<0.001***	***P1***
	TCNS 228	626	0.512	0.274	0.091	0.444	2.183	204	0.505	0.267	0.115	0.404	1.199	0.485	P1
	TCNS 230	***620***	***0.407***	***0.251***	***0.080***	***0.341***	***1.861***	***150***	***0.613***	***0.270***	***0.196***	***0.591***	***1.440***	***<0.001***	***P2***
	TCNS 233	***720***	***0.390***	***0.260***	***0.069***	***0.298***	***1.758***	***246***	***0.663***	***0.372***	***0.176***	***0.592***	***2.237***	***<0.001***	***P2***
	TCNS 249	***174***	***0.457***	***0.396***	***0.045***	***0.315***	***2.379***	***54***	***0.196***	***0.151***	***0.060***	***0.151***	***0.739***	***0.002***	***P1***

Note. Bolded and italicized data indicate that a statistically signficant difference was determined for the two sampling periods at α = 0.05.

Table 8-9. Summary of TN concentrations collected at during the baseline period from 1991–2001 and BMP implementation period from 2002–2011.

Basin	Station	Summary Statistics for Period from 1991 to 2001						Summary Statistics for Period from 2002 to 2011						Mann-Whitney p-value	Higher Period
		No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum	No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum		
S-65A	KREA 79	65	1.259	0.414	0.580	1.140	2.290	115	1.276	0.372	0.790	1.200	2.850	0.647	P2
	KREA 91	50	1.395	0.495	0.250	1.310	2.860	104	1.485	0.411	0.820	1.390	2.880	0.798	P2
	KREA 92	59	1.114	0.281	0.510	1.080	1.790	112	1.109	0.172	0.820	1.085	1.980	0.908	P2
	KREA 97	50	1.281	0.325	0.550	1.275	2.000	95	1.470	0.323	0.960	1.410	2.630	0.527	P2
S-65BC	***KREA 93***	***55***	***1.442***	***0.465***	***0.710***	***1.300***	***2.820***	***108***	***1.255***	***0.263***	***0.590***	***1.200***	***2.150***	***0.030***	***P1***
	KREA 94	48	1.417	0.463	0.820	1.250	2.950	110	1.272	0.278	0.630	1.195	2.170	0.070	P1
	KREA 95	***59***	***1.291***	***0.358***	***0.770***	***1.210***	***2.340***	***108***	***1.169***	***0.280***	***0.640***	***1.140***	***3.070***	***0.012***	***P1***
	KREA 98	41	1.373	0.387	0.740	1.330	2.340	106	1.273	0.263	0.580	1.205	2.380	0.246	P1
S-65D	***KREA 01***	***162***	***1.436***	***0.564***	***0.250***	***1.305***	***5.400***	***131***	***1.680***	***0.460***	***0.880***	***1.650***	***3.120***	***<0.001***	***P2***
	KREA 04	***72***	***1.358***	***0.401***	***0.520***	***1.370***	***2.690***	***110***	***1.564***	***0.374***	***0.910***	***1.520***	***3.150***	***0.018***	***P2***
	KREA 06A	33	1.355	0.383	0.250	1.300	2.280	97	1.561	0.547	0.860	1.510	4.890	0.773	P2
	KREA 22	***104***	***1.443***	***1.035***	***0.510***	***1.245***	***8.980***	***128***	***1.488***	***0.415***	***0.490***	***1.425***	***2.810***	***0.005***	***P2***
	KREA 23	80	1.322	0.352	0.640	1.265	2.370	100	1.425	0.470	0.790	1.310	4.080	0.272	P2
S-65E	KREA 14	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	60	2.009	0.731	0.440	1.940	4.200	-NA-	-NA-
	KREA 17A	***112***	***1.413***	***0.381***	***0.250***	***1.350***	***2.970***	***135***	***1.783***	***0.407***	***0.850***	***1.710***	***3.140***	***<0.001***	***P2***
	KREA 19	40	2.112	0.719	0.850	2.115	3.380	96	2.230	0.926	0.740	2.065	4.200	0.814	P1
	KREA 41A	***29***	***2.319***	***1.430***	***0.690***	***1.850***	***8.890***	***50***	***2.893***	***0.872***	***0.900***	***2.890***	***4.760***	***0.004***	***P2***
S-154	KREA 20	55	2.625	0.971	1.160	2.440	6.010	27	3.023	1.313	0.620	3.270	7.060	0.234	P2
	KREA 25	77	2.292	0.683	0.600	2.160	4.180	39	2.329	0.608	1.120	2.360	3.820	0.925	P2
	KREA 28	326	2.158	0.565	0.250	2.120	4.210	187	2.294	0.745	1.260	2.180	6.510	0.613	P2
	KREA 30A	201	1.973	0.493	0.620	1.900	4.480	36	1.924	0.433	0.930	1.930	3.050	0.577	P2
S-191TC	TCNS 201	226	1.492	0.569	0.520	1.480	4.290	166	1.669	0.599	0.650	1.680	2.860	0.061	P2
	TCNS 204	***50***	***2.574***	***1.185***	***1.500***	***2.330***	***6.740***	***174***	***3.660***	***0.709***	***2.200***	***3.600***	***5.790***	***<0.001***	***P2***
	TCNS 207	***648***	***2.013***	***2.642***	***0.250***	***1.450***	***27.860***	***258***	***3.207***	***2.317***	***0.750***	***2.630***	***22.920***	***<0.001***	***P2***
	TCNS 209	***670***	***1.613***	***1.679***	***0.250***	***1.360***	***17.560***	***246***	***1.847***	***0.643***	***0.660***	***1.850***	***4.040***	***<0.001***	***P2***
	TCNS 212	19	1.821	0.536	0.810	1.760	2.730	38	1.665	0.577	0.990	1.555	3.310	0.231	P1
	TCNS 213	***646***	***1.689***	***0.909***	***0.250***	***1.520***	***9.270***	***388***	***2.064***	***0.677***	***0.800***	***1.945***	***4.810***	***<0.001***	***P2***
	TCNS 214	718	1.250	0.601	0.250	1.200	3.740	368	1.256	0.611	0.330	1.185	2.890	0.289	P1
	TCNS 217	***345***	***2.319***	***5.743***	***0.250***	***1.580***	***89.620***	***199***	***1.342***	***0.620***	***0.430***	***1.190***	***3.900***	***<0.001***	***P1***
S-191NS	***TCNS 220***	***31***	***2.694***	***1.105***	***1.630***	***2.410***	***5.740***	***92***	***2.775***	***1.312***	***0.990***	***2.590***	***10.830***	***0.015***	***P2***
	TCNS 222	***674***	***1.912***	***0.735***	***0.250***	***1.800***	***9.680***	***286***	***1.945***	***0.508***	***0.810***	***1.890***	***4.340***	***<0.001***	***P2***
	TCNS 228	612	2.299	0.915	0.250	2.200	9.030	202	2.319	0.901	0.980	2.230	6.370	0.884	P2
	TCNS 230	***608***	***1.786***	***0.527***	***0.250***	***1.705***	***4.600***	***146***	***2.059***	***0.509***	***1.090***	***1.990***	***3.950***	***<0.001***	***P2***
	TCNS 233	***708***	***1.758***	***0.546***	***0.250***	***1.675***	***4.320***	***242***	***2.333***	***1.638***	***1.060***	***2.010***	***16.130***	***<0.001***	***P2***
	TCNS 249	32	1.102	0.643	0.250	1.160	2.960	24	1.243	0.543	0.570	1.145	3.250	0.519	P1

Note. Bolded and italicized data indicate that a statistically signficant difference was determined for the two sampling periods at $\alpha = 0.05$.

Table 8-10. Summary of TP concentrations collected at the dairy sites during the baseline period from 1991–2001 and BMP implementation period from 2002–2011.

Station	Summary Statistics for Period from 1991 to 2001						Summary Statistics for Period from 2002 to 2011						Mann-Whitney p-value	Higher Period
	No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum	No of Samples	Mean	Standard Deviation	Minimum	Median	Maximum		
KREA 07	248	0.596	0.415	0.029	0.538	2.807	152	0.883	1.411	0.049	0.478	11.154	0.555	P1
KREA 08	***226***	***1.162***	***0.558***	***0.018***	***1.085***	***3.170***	***184***	***1.014***	***0.630***	***0.195***	***0.910***	***3.410***	***<0.001***	***P1***
KREA 10D	***324***	***0.751***	***0.985***	***0.018***	***0.476***	***8.172***	***268***	***0.451***	***0.658***	***0.020***	***0.216***	***4.023***	***<0.001***	***P1***
KREA 43A	***372***	***0.777***	***0.553***	***0.046***	***0.653***	***4.159***	***186***	***1.112***	***0.915***	***0.100***	***0.837***	***5.368***	***<0.001***	***P2***
KREA 46A	210	0.984	0.827	0.002	0.809	6.430	52	0.820	0.385	0.286	0.760	1.490	0.513	P1
KREA 49	***178***	***5.072***	***2.486***	***0.231***	***4.872***	***11.000***	***176***	***2.578***	***1.530***	***0.069***	***2.629***	***7.541***	***<0.001***	***P1***
TCNS 210	***294***	***1.018***	***0.717***	***0.032***	***0.840***	***6.136***	***194***	***2.007***	***2.928***	***0.077***	***1.095***	***24.300***	***<0.001***	***P2***
TCNS 211	***476***	***0.222***	***0.289***	***0.019***	***0.117***	***1.768***	***312***	***0.175***	***0.225***	***0.012***	***0.087***	***1.542***	***0.002***	***P1***
TCNS 231	444	1.097	0.694	0.102	0.948	3.921	166	1.337	1.243	0.183	0.855	6.868	0.527	P1
TCNS 243	182	0.187	0.199	0.013	0.090	0.912	120	0.150	0.155	0.023	0.104	1.020	0.827	P2
TCNS 262	***544***	***1.412***	***0.769***	***0.024***	***1.325***	***5.730***	***292***	***0.819***	***0.836***	***0.199***	***0.638***	***9.500***	***<0.001***	***P1***
TCNS 263	***520***	***1.415***	***0.830***	***0.209***	***1.326***	***6.888***	***226***	***0.772***	***0.485***	***0.373***	***0.664***	***3.728***	***<0.001***	***P1***
TCNS 265	***386***	***0.429***	***0.339***	***0.011***	***0.330***	***2.202***	***296***	***0.480***	***0.316***	***0.115***	***0.408***	***1.817***	***<0.001***	***P2***
TCNS 277	***378***	***1.371***	***0.573***	***0.033***	***1.304***	***3.932***	***214***	***0.682***	***0.555***	***0.084***	***0.562***	***5.174***	***<0.001***	***P1***
TCNS 280	***242***	***6.100***	***2.398***	***1.309***	***5.819***	***14.345***	***82***	***4.501***	***1.507***	***2.460***	***4.373***	***9.807***	***<0.001***	***P1***
TCNS 281	***284***	***0.718***	***0.383***	***0.157***	***0.659***	***2.543***	***138***	***0.463***	***0.257***	***0.066***	***0.398***	***1.071***	***<0.001***	***P1***

Note: Bolded and *italicized* data indicate a statistically significant difference for the two sampling periods at α = 0.05.

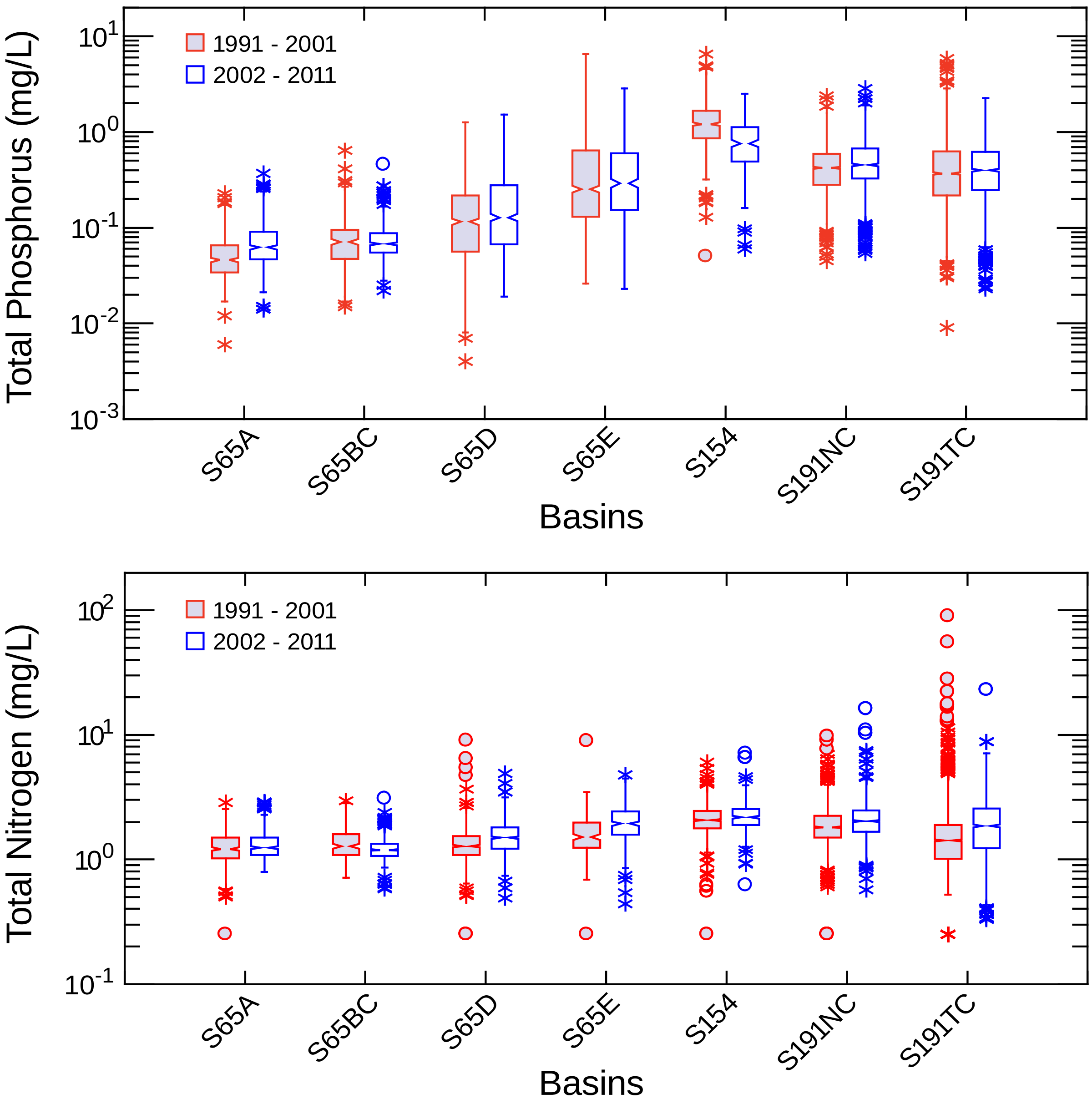


Figure 8-10. Box-and-whisker plot of TP (top panel) and total nitrogen (TN) (bottom panel) concentrations in milligrams per liter (mg/L) for the periods of 1991–2001 and 2002–2011.

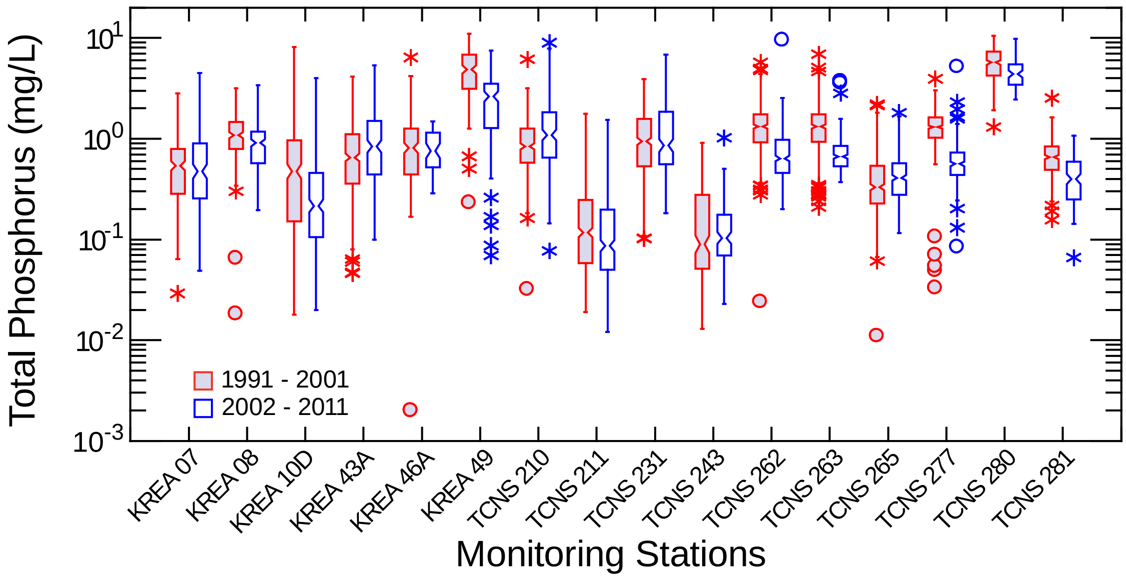


Figure 8-11. Box-and-whisker plot of TP concentrations for the periods of 1991–2001 and 2002–2011 for the monitoring stations located at individual dairy farms.

LAKE STATUS

PERFORMANCE MEASURES

Measurements of TP, chlorophyll *a* (Chl*a*), phytoplankton, submerged aquatic vegetation (SAV), and water levels are used as quantitative performance measures for the NEEPP. These measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are five-year averages to ensure consistency with TMDL reporting, reduce year-to-year variation due to climate and hydrology, and improve understanding of underlying trends. These values are compared to quantitative restoration goals (**Table 8-11**). The Lake Okeechobee Protection Plan provides a technical foundation for these restoration goals (SFWMD et al., 2004). The WY2012 averaged observations document current water quality and lake level conditions.

In WY2012, eight of the performance measures improved over the previous year. These include lower pelagic TP, TN, soluble reactive phosphorus (SRP), and dissolved inorganic nitrogen (DIN); increased pelagic TN to TP ratio (by mass); lower frequency of algal blooms; increased water clarity; lower nearshore TP; and increased total SAV. The diatom-to-cyanobacteria ratio by biovolume, with a 2:4 current five-year (WY2008–WY2012) average, met its goal (**Table 8-11**).

SAV did not reach the goal of 40,000 ac with 20,000 ac as vascular plants either in the average of the previous five years of data (August 2007–August 2011) (**Table 8-11**) nor in the August 2011 survey. A further evaluation of the last survey is provided in the *Submerged Aquatic Vegetation* section of this document.

Table 8-11. Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions for WY2008–WY2012, as specified in the Restoration Assessment Plan of the Lake Okeechobee Watershed Protection Program (LOWPP). WY2012 and WY2011 values are included to show annual changes. [Note: acres – ac; DIN – dissolved inorganic nitrogen; ft – feet; mt/yr – metric tons per year; N – nitrogen; NA – not applicable; P - phosphorus; SAV – submerged aquatic vegetation; SRP – soluble reactive phosphorus; µg/L – micrograms per liter.]

Performance Measure	Goal	Five-Year Average	WY2012	WY2011
TP load	140 mt/yr	387 mt/yr	377 mt/yr	177 mt/yr
N Load	NA	4,788 mt/yr	4,620 mt/yr	2,913 mt/yr
Pelagic TP	40 ppb	134 ppb	92 ppb	108 ppb
Pelagic TN	NA	1.52 ppm	1.33 ppm	1.46 ppm
Pelagic SRP	NA	42 ppb	26 ppb	32 ppb
Pelagic DIN	NA	191 ppb	134 ppb	178 ppb
Pelagic TN:TP	> 22:1	11.3:1	14.5:1	13.4:1
Pelagic DIN:SRP	> 10:1	4.5:1	5.6:1	5.6:1
Plankton nutrient limitation	P > N	N >>> P	N >>> P	N >>> P
Diatom:cyanobacteria ratio [a]	> 1.5	2.4	NA	NA
Algal bloom frequency	< 5 percent of pelagic chlorophyll *a* exceeding 40 mg/L	7.4 percent	1.1 percent	16.5 percent
Water clarity	Secchi disk visible on lake bottom at all nearshore SAV sampling locations from May to September[c]	44.0 percent	83 percent	58 percent
Nearshore TP	Below 40 ppb	68 ppb	58 ppb	61 ppb
SAV[b]	Total SAV > 40,000 ac	33,629 ac total	36,325 ac total	27,388 ac total
	Vascular SAV > 20,000 ac	11,489 ac vascular	8,896 ac vascular	19,596 ac vascular
Extremes in low lake stage (current water year)	Maintain stages above 10 ft	NA	Goal Not attained	Goal attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than 4 months	NA	Goal attained	Goal attained
Spring recession (January to June)	Stage recession from near 15.5 ft in January to near 12.5 ft in June	NA	Partial attainment (13.7 on January 1 to 11.7 on June 1	Goal not attained

a. Mean values from May 2005 to February 2010.
b. Mean yearly acreages (from August 2007–August 2011 maps).
c. SAV transparency readings for nearshore monitoring stations May to September.

Dry conditions throughout most of WY2012 resulted in water levels that declined to below the 10-foot low lake criteria for approximately 45 days (**Figure 8-12**, **Table 8-11**). Because of the dry conditions, the high lake stage criterion was not exceeded. From January 2012 to June 2012, water levels declined from 13.7 ft (4.18 m) to 11.7 ft (3.57 m) NGVD (**Figure 8-12**). This was parallel but below the spring recession criteria of 15.5 ft (4.72 m) in January and 12.5 ft (3.81 m) in June.

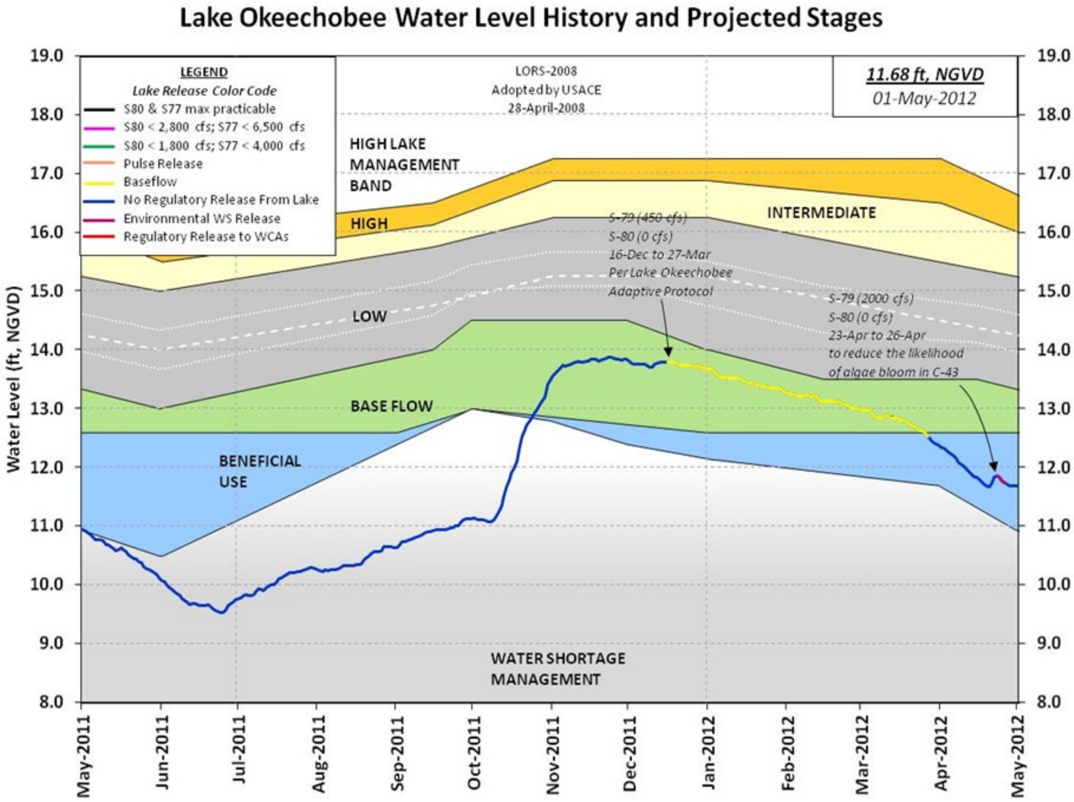


Figure 8-12. Annotated Lake Okeechobee stage [in feet (ft) National Geodetic Vertical Datum of 1929 (NGVD)] hydrograph.

HYDROLOGY

The Lake Okeechobee water level began WY2012 at an elevation of 10.92 feet NGVD, which placed it in the Water Supply Management Band according to the 2008 LORS. Due to continued dry weather in May and June, the lake level declined to 9.68 feet on June 27, 2011, reaching its lowest level for this water year. In response to the eventual onset of the rainy season, the lake began a gradual rise towards 11 ft NGVD until heavy rains in October resulted in a rapid spike in lake level culminating in a maximum elevation of 13.84 ft NGVD in late November 2011, returning the lake to the 2008 LORS Base Flow Sub-band. The lake ended the water year in the Beneficial Use Sub-band at an elevation of 11.68 ft NGVD. No releases to the St. Lucie Estuary were made during this water year. Two series of releases were made to the Caloosahatchee River (C-43 Canal) and Estuary. The first, from December 16, 2011 to March 27, 2012 was for the purpose of high salinity mitigation below the S-79 structure. The second, which occurred from April 23 to April 26, 2012, was for the purpose of flushing out algal bloom conditions that had developed upstream of the S-79 structure (**Figure 8-12**).

NUTRIENT BUDGETS

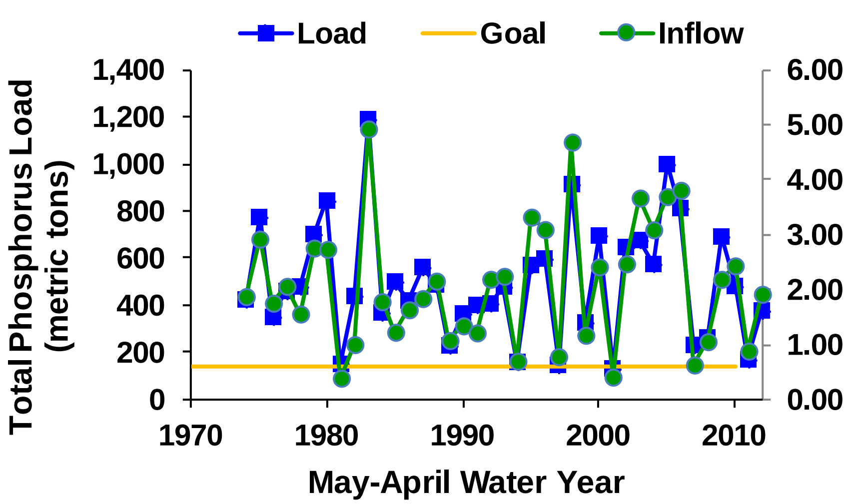
TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt/yr) (FDEP, 2001) totaled 377 mt in WY2012 (**Table 8-12** and **Figure 8-13**). This was more than double the load from WY2011 and was due to the increased inflow contributed from the October storm. Mean lake TP mass in WY2012 was 27 percent less than the previous water year due to 16 percent lower water volume and 14 percent lower water column concentrations (**Table 8-12** and **Figure 8-14**). Net change in lake content was only 10 mt (**Table 8-12**). Loads out of the lake were 58 percent lower in WY2012 than in WY2011 as discharge was 52 percent less. The net load (inputs minus outputs) in WY2012 was 289 mt because of the smaller load out than load in. Sediment accumulation was 10 percent less than the previous year. However, the 279 mt of TP that accumulated in the sediments resulted in a net sedimentation coefficient (sediment accumulation/mean lake TP mass) of 0.91 (**Table 8-12** and **Figure 8-15**).

Table 8-12. TP budget for Lake Okeechobee for the most recent 10 water years.

Water Year	Mean Lake TP Mass	Net Change in Lake Content[a]	Load In[b] (mt)	Load Out (mt)	Net Load[c] (mt)	Sediment Accumulation[d]	Net Sedimentation Coefficient (s_Y)
2003	594	143	639	317	322	179	0.30
2004	578	113	553	302	251	138	0.24
2005	1108	270	960	582	378	108	0.10
2006	1104	-194	795	798	-3	191	0.17
2007	593	-269	203	176	27	296	0.50
2008	462	132	246	26	220	88	0.19
2009	602	-276	656	242	414	690	1.15
2010	490	291	478	77	401	110	0.22
2011	428	-338	177	208	-31	307	0.72
2012	307	10	377	88	289	279	0.91
Average	**627**	**-12**	**508**	**282**	**226**	**238**	**0.45**

a. Net change from the start (May 1) through the end (April 30) of each water year.
b. Includes 35 mt/yr to account for atmospheric deposition.
c. Difference between load in and load out.
d. Difference between net change in lake content and net load (positive value is accumulation in sediments).

Figure 8-13. Timelines of water year TP load and inflow entering Lake Okeechobee from its tributaries calculated from the P budget of Lake Okeechobee.



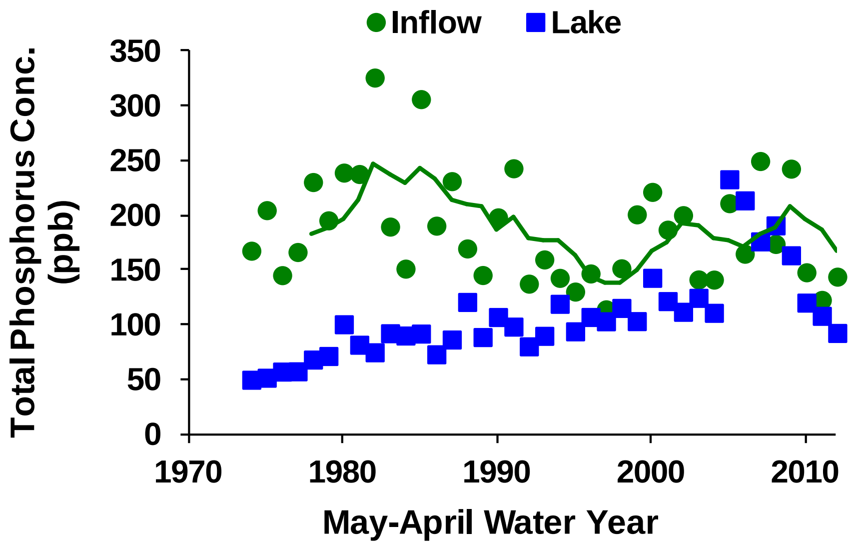


Figure 8-14. Timelines of inflow and lake average TP concentrations (five-year moving average trend lines calculated from the TP budget of Lake Okeechobee). [Note: Conc. – Concentration.]

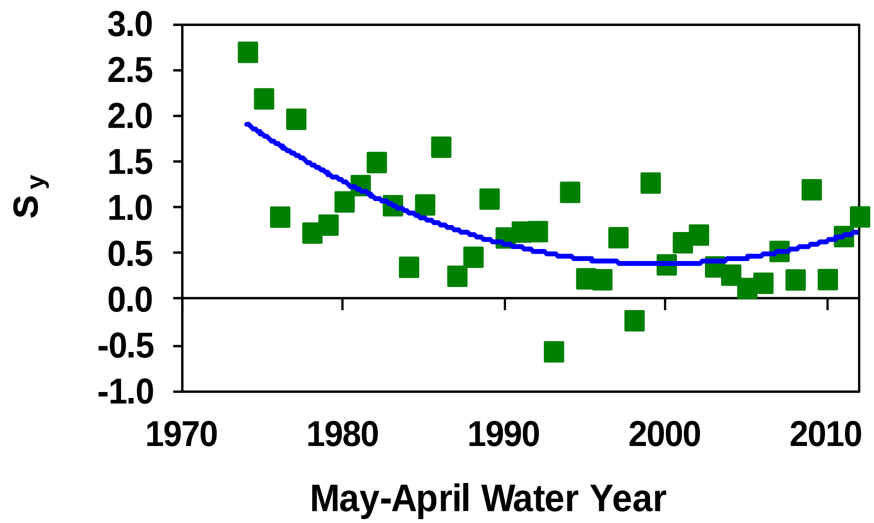


Figure 8-15. Timeline of the net sedimentation coefficient (s_y) calculated from the WY2012 TP budget of Lake Okeechobee. (Trend line is a second-order polynomial.)

P concentrations in the lake water column have declined each year after reaching a maximum yearly average value of 233 ppb in 2005 (**Figure 8-14**). In WY2012, the average value was 92 ppb (**Table 8-11**), such a low average annual value has not been observed since 1993 (**Figure 8-14**). This low TP concentration is attributed to multiple factors: increased SAV abundance, reduced water levels, reduced inflow TP concentration, improved light conditions, and reduced suspended solids as sediments have reconsolidated following the hurricanes.

The net sedimentation coefficient, s_y (per year), of the P budget is the amount of TP that accumulates in the sediment per year divided by the average lake water TP mass (**Table 8-12** and **Figure 8-15**). A low s_y indicates that the lake absorbs less excess TP loads from the watershed. For WY2012, the s_y value was 0.91 per year (**Table 8-12**), which is above the 10-year average value of 0.45 per year. The WY2012 value is 25 percent higher than the previous year's estimate indicating increased absorption of P by sediments. Over the past four decades s_y declined from around 2.5 in the 1970s to below 1 in the 1990s (**Figure 8-15)** (Janus et al., 1990; James et al., 1995; Havens and James, 2005**).**

Loads of N to the lake are approximately tenfold greater than P (**Table 8-13**). Annual loads also are closely related to the hydrology of the lake, fluctuating between 2,500 and 14,000 mt/yr (**Figure 8-16**). Discharge loads from the lake are approximately half of the inflow loads (**Table 8-13**). Inflow N concentrations tend to be higher than either in-lake or outflow concentrations while outflow concentrations tend to be slightly higher than in-lake concentrations (**Figure 8-17**). This is probably a result of the intra-annual variability of N in the lake, with higher N levels in winter than in summer (Maceina and Soballe, 1990), and increased discharge of water in the late winter and spring.

Despite this difference between loads into and out of the lake, concentrations of N in the lake have been relatively stable since the 1980s (**Figure 8-17**). This stability is likely due to biological processes in the lake that remove N through the denitrification process (James et al., 2011). Evidence of this uptake is observed in the lake adsorption rate, which averages more than 50 percent of the load in to the lake (**Table 8-13**).

Table 8-13. N budget for Lake Okeechobee for the most recent 10 water years.

May 1–April 30 Water Year	Mean Lake TN Mass	Net Change in Lake Content[a]	Load In[b] (mt)	Load Out (mt)	Net Load[c] (mt)	Lake Adsorption[d]	Net Adsorption Coefficient (s_y)
2003	7,630	1,426	8,279	4,165	4,115	2,689	0.35
2004	6,924	-208	6,526	4,642	1,884	2,092	0.30
2005	10,023	2588	8,775	6,609	2,166	-422	-0.04
2006	9,389	-2,692	7,992	8,048	-56	2,636	0.28
2007	4,873	-3,460	2,965	2,023	942	4,402	0.90
2008	3,772	2,128	3,393	392	3,001	873	0.23
2009	6,566	-1,075	6,689	2,841	3,848	4,923	0.75
2010	6,659	2,735	6,325	1,106	5,219	2,484	0.37
2011	5,762	-3,402	2,913	3,018	-105	3,297	0.57
2012	4,427	487	4,620	1,460	3,160	2,673	0.60
Average	**6,603**	**-147**	**5,848**	**3,430**	**2,417**	**2,565**	**0.43**

a. Net change from the start (May 1) through the end (April 30) of each water year.
b. Includes 1,233 mt/yr to account for atmospheric deposition.
c. Difference between load in and load out.
d. Difference between net change in lake content and net load (positive value is accumulation in sediments).

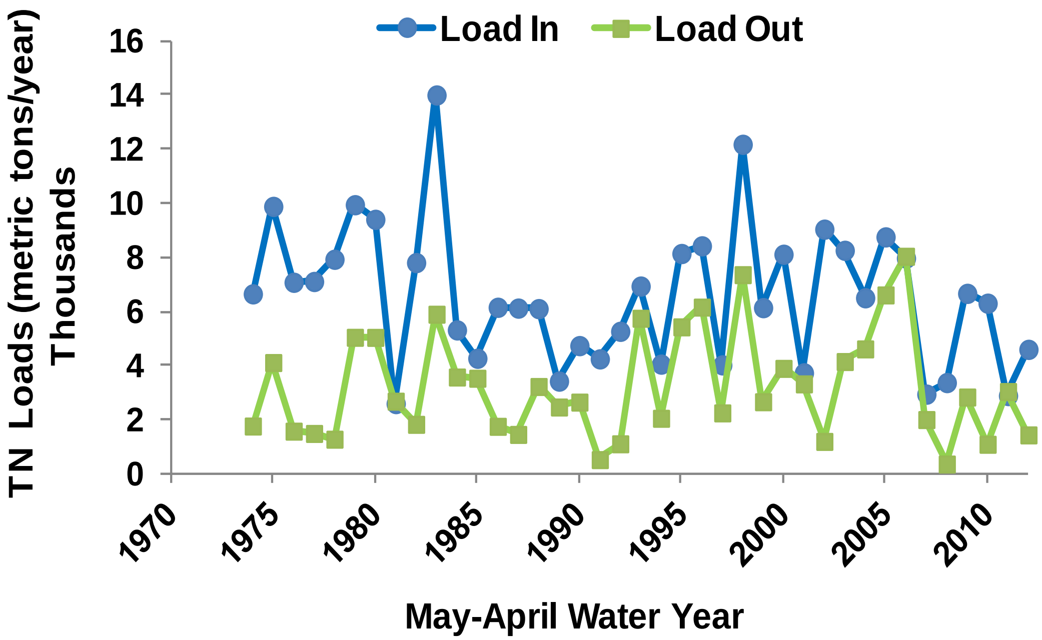


Figure 8-16. Timeline of water year inflow and outflow nitrogen (N) load to and from Lake Okeechobee calculated from the N budget of the lake.

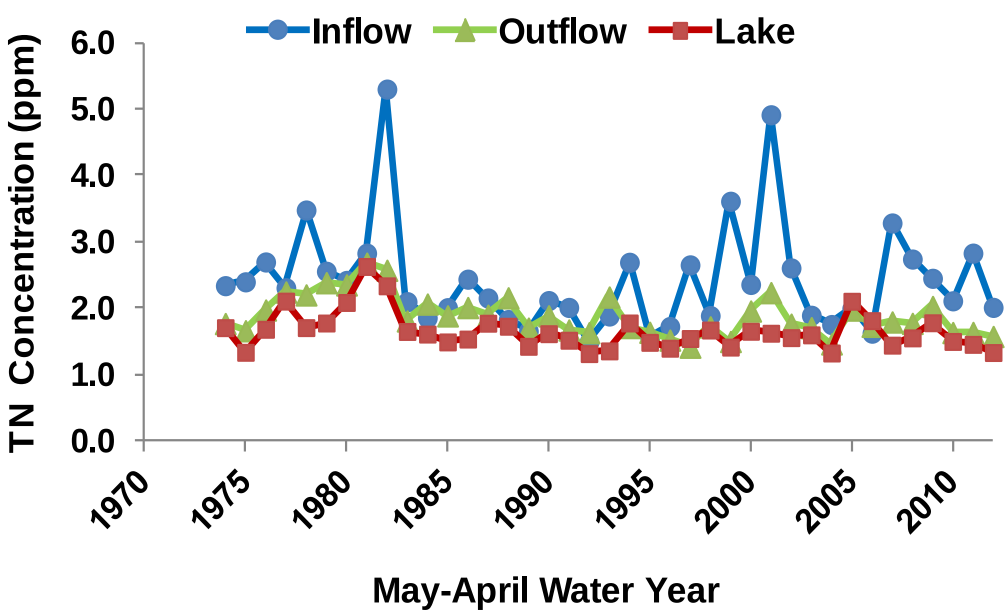


Figure 8-17. Timelines of inflow, outflow, and lake average TN concentrations calculated from the N budget of Lake Okeechobee.

IN-LAKE MONITORING

MONITORING AND RESEARCH REDUCTION EFFORTS

As part of a District-wide effort to reduce monitoring and research costs and refocus on its core mission, all Lake Okeechobee related ecological monitoring and research was subjected to review this past year. While a final decision is still pending, we anticipate a reduction in either the frequency or number of stations sampled, or both, for our routine plankton monitoring and aerial vegetation mapping work, and the elimination of our macroinvertebrate, periphyton, and herpetofauna monitoring programs. We also anticipate that our apple snail breeding and stock enhancement research, a related project examining the potential for the bioaccumulation of aluminum in apple snails living in waters receiving discharge from alum-based nutrient (P) abatement facilities (to be reported on in the next SFER) will be brought to expeditious completion and terminated. It also should be noted here that the Lake Okeechobee fishery monitoring provided in this report is conducted by the Florida Fish and Wildlife Conservation Commission (FWC) and is dependent on their ability to continue funding this annual effort.

SUBMERGED AQUATIC VEGETATION

SAV abundance, a key indicator of the lake's overall ecological health, has been monitored on Lake Okeechobee since April 1999 (WY1999). Over the 13-year period, few changes have been made to either the Annual Mapping or Transect Mapping programs. The last change occurred in the Transect Mapping project in WY2011 when the labor intensive quantitative sampling was eliminated and only visual estimates of biomass (sparse, moderate, and dense) were reported along the 16 fixed transects. Sampling frequency was also reduced from monthly to quarterly (see the 2012 SFER– Volume I, Chapter 8 for details). Additional methodological modifications were made to both programs in WY2011 and WY2012. These changes were made in an effort to (1) provide more accurate and precise reporting of areal coverage data, (2) make the transect monitoring data more comparable to the annual mapping data thus providing more information to scientists and stakeholders, and (3) streamline the sampling process and make it less labor intensive and more cost effective.

Annual Mapping Modifications

Since 2000 (WY2001), the entire nearshore SAV community of Lake Okeechobee has been mapped with an intensive program that includes 628 sites around the shoreline. This sampling is done in August on a 1-km^2 resolution sampling grid developed in Geographic Information Systems (GIS). The total spatial extent, species distribution, and acreage of SAV in the nearshore are calculated and maps of the dominant species are developed. Beginning in August 2010 (WY2011), the 1-km^2 sampling grid was extended into the marsh to incorporate SAV present in this habitat as well (**Figure 8-18**). This resulted in an additional 357 sites for a total of 985 sites. From this point on, the spatial extent of SAV for the nearshore sites will be reported separately from the SAV coverage for the marsh sites so comparisons with pre-2010 (WY2011) results (nearshore only) can still be made. . . . . . .

During this recent methodology change, areal coverage calculation differences in past mapping results were revealed. Acreages reported prior to 2008 (WY 2009) were calculated slightly differently than those reported post-2008 (WY 2009). This discrepancy was due to a combination of advancements in GIS technology and changes in personnel. In an effort to make the results from all years comparable, the post-2008 (WY 2009) acreages were recalculated using the pre-2008 (WY 2009) methods.

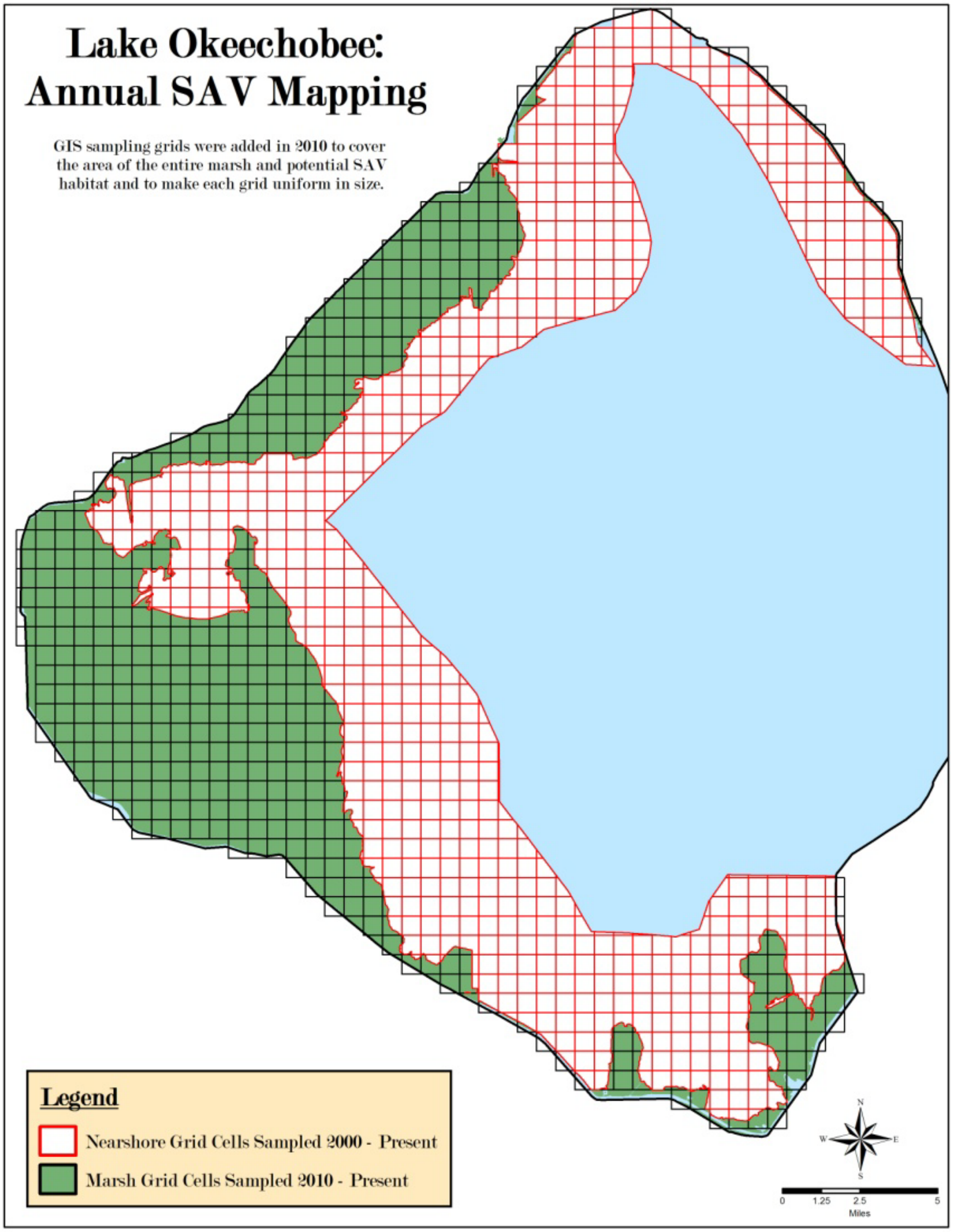


Figure 8-18. Map showing the extension of the annual submerged aquatic vegetation (SAV) mapping 1-square kilometer (km^2) grid cells to incorporate the marsh habitat. The grid cells outlined in red are the nearshore grid cells that have been sampled since 2000 (WY2001). The grid cells outlined in black are the marsh grid cells that were added in 2010 (WY2011).

Transect Mapping Modifications

SAV monitoring prior to 2011 (WY2012) was conducted at sites located along 16 fixed transects encompassing the lake's north, south, and west shoreline. The basis for choosing these sites was that they represented a subset of sites sampled in the Lake Okeechobee Ecosystem Study (Zimba, 1995) in the late 1980s and early 1990s, and covered the region where SAV beds historically occurred. This allowed for comparisons with the historical data. Unfortunately, these sites had no relationship with the grid cells that were sampled during the annual mapping in August of each year so no direct comparisons could be made with the annual data collected over the past 11 years. To make the transect data comparable to the annual data, SAV sampling in 2011 (WY 2012) began to be done along transects created using a subset of the grid cells sampled for the annual grid map (**Figure 8-19**). Because the sites and the sampling techniques are now identical in the two mapping efforts, results from past annual mappings can be plotted and compared with the results from the new quarterly transect mapping. An added benefit to using a subset of grid cells from the annual mapping grid is that the results from the August annual sampling can also be used for the August quarterly sampling event so only one sampling trip is needed. Quarterly transect sampling is conducted in February, May, August, and November. This effectively eliminates one sampling trip during the year, saving time, resources, and money.

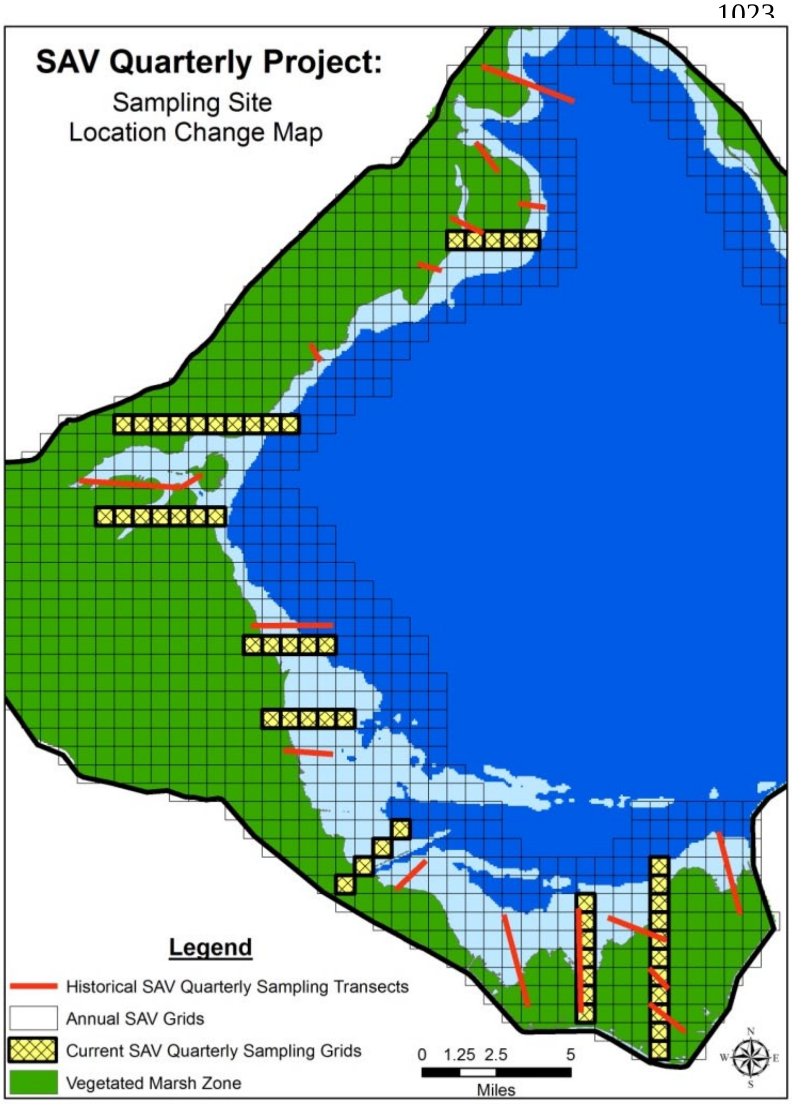


Figure 8-19. Map showing the change in SAV transect mapping locations. The current transect sites are a subset of the annual mapping grid (grid cell size = 1 km^2). The 16 transects sampled prior to 2011 (WY2012) are depicted by the bold red lines and the 7 transects currently sampled are depicted by the yellow X-grid cells.

Results

Areal coverage of nearshore SAV, as measured in August of each year, has varied between approximately 28,000 and 51,000 ac since 2007 (WY2008) (**Figure 8-20**). This is a substantial increase from the 3,000 ac reported in 2006 (WY2007) after two years of hurricanes, indicating a period of recovery. In 2011 (WY2012), areal coverage for nearshore vascular SAV [tape grass (*Vallisneria americana*) – 6,919 ac; hydrilla (*Hydrilla verticillata*) – 6,178 ac; pondweed (*Potamogeton* spp.) – 494 ac, and hornwort (*Ceratopyllum* spp. – 2,718 ac)] were all lower than pre-hurricane levels. This appears to be primarily due to a decrease in nearshore colonizable area associated with low lake levels related to both drought and the current lake operating schedule (2008 LORS). The low lake levels experienced over the past decade have resulted in previously SAV-dominated areas in the nearshore becoming dominated by emergent and terrestrial plants. For example, approximately 7,000 ac that was open water SAV habitat in South Bay prior to 2007 (WY2008) has changed to emergent marsh habitat. Conversely, the areal coverage of musk grass (*Chara* spp.), a non-vascular macroalga, in the nearshore was 27,429 ac, which is similar to or higher than pre-hurricane levels. Unlike the vascular species, this species has colonized an area offshore of where it was found historically at a rate proportional to its loss from the newly formed marsh habitat.

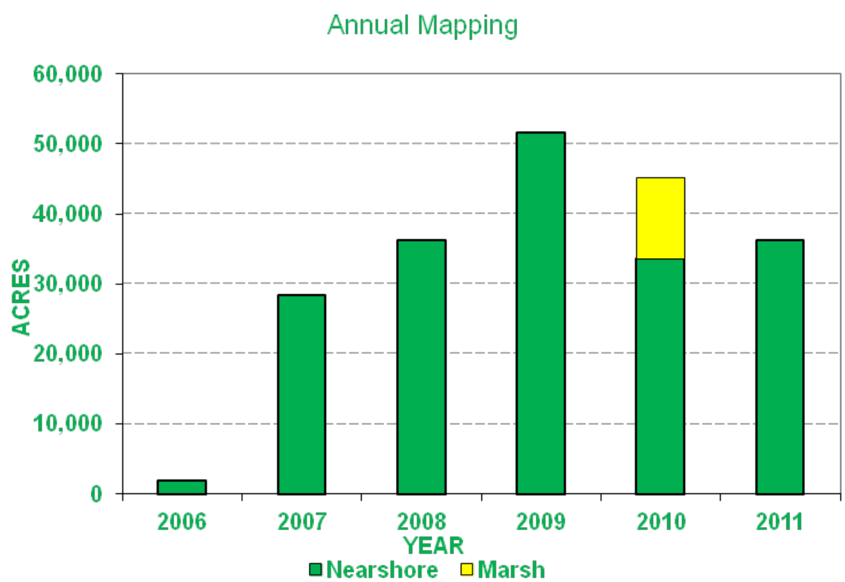


Figure 8-20. Annual SAV mapping results for 2006–2011 (WY2007–WY2012).

Although SAV mapping in the marsh began in 2010 (WY2011) and there were over 11,000 ac of SAV present, lake levels were so low in 2011 (WY2012) that the marsh was dry and inaccessible (**Figure 8-12**).

Current density estimates from the quarterly transect sampling also show that SAV in Lake Okeechobee continues to recover from the recent hurricanes and extremely low lake levels (**Figure 8-21**). Even though density values are not as high as they were prior to the hurricanes, there has been a gradual increase in both the number of sites with plants and in the number of sites with moderate [5 to 50 grams dry weight per square meter (g dw/m^2) to dense (greater than 50 g dw/m^2) biomass since the 2011 (WY2012) annual mapping.

Over the past five water years, Lake Okeechobee achieved its rehabilitation performance measure of 40,000 ac of nearshore SAV with 50 percent or more consisting of vascular species only in 2009 (WY2010). However, the viability of this metric may need to be reevaluated given the change in operating schedule. If lake stages continue to remain near the lower end of the desired stage envelope or lower, the enlarged marsh habitat likely will continue to occupy formerly open water SAV habitat while SAV colonizes areas offshore. However, vascular species appear not to be able to colonize this area as readily as the non-vascular species musk grass, which is consistent with its reputation as a pioneer species.

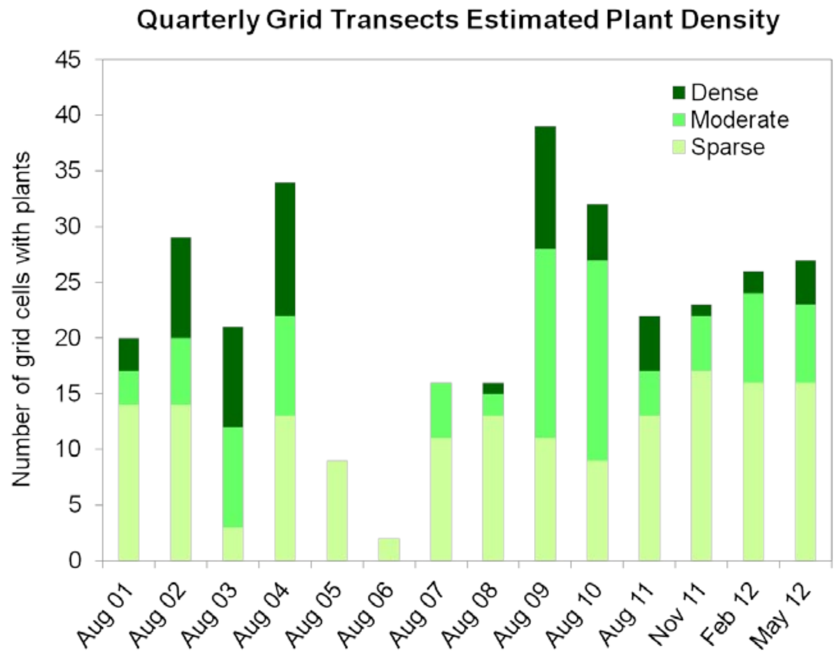


Figure 8-21. Estimated plant densities along the 7 transects on annual basis from August 2001 (WY2002) to August 2011 (WY2012) and on a quarterly basis from November 2011 (WY2012) to May 2012 (WY2013).

EMERGENT VEGETATION

Lake Okeechobee Vegetation Mapping

The composition, distribution, and areal coverage of Lake Okeechobee's emergent marsh community are strongly influenced by hydrologic conditions, vegetation management actions, and competition between species, especially when native habitats are impacted by invasive exotic plants.

Color infra-red aerial photography was collected in 2011 and used to create a detailed GIS vegetation map of Lake Okeechobee's northwest marsh. The marsh was equally divided into 100 m by 100 m grids [1 hectare (ha)] and the dominant and secondary plant communities within each grid were identified and recorded. A section of the 2011 vegetation map was used to evaluate and quantify significant temporal changes that occurred in the Worm Cove region of the marsh south of Indian Prairie Canal following a drought, a fire, and a muck and vegetation removal project. In 2003, plant diversity was low and dominated by cattail (202 ha), open water (125 ha), and floating plants (79 ha). Much of the area that was dominated by dense monotypic cattail (*Typha* spp.) (not a desirable habitat for fish and other wildlife) in 2003 transitioned to a more open lily community (243 ha) in 2011. The lily community also expanded lakeward reducing the open water area to 27 ha. In addition, bulrush (*Schoenoplectus californicus*) and aquatic grasses expanded along the outside edge of the marsh creating favorable fish and wildlife habitat (**Figure 8-22**).

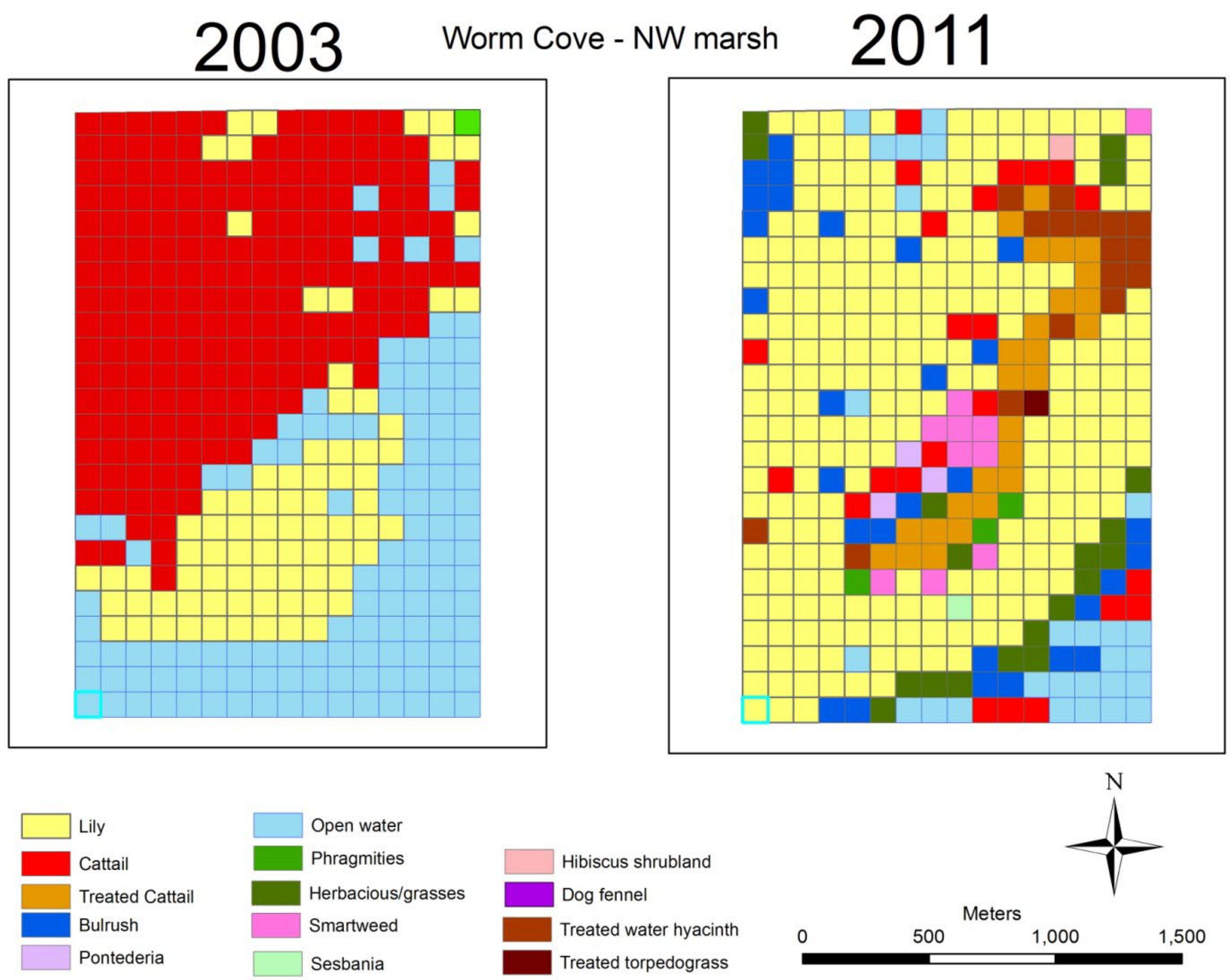


Figure 8-22. Vegetation maps of the Worm Cove region of Lake Okeechobee's western marsh showing the dominant plant communities that were present in 2003 and 2011. There was a large reduction in dense cattail and an expansion of the lily community between years.

The Lake Okeechobee marsh vegetation maps are also being used to evaluate snail kite nesting and foraging habitat. For example, **Figure 8-23** shows a color infrared image of a portion of the Harney Pond marsh including the location of a snail kite nest located in cattail while **Figure 8-24** shows the dominant nesting and foraging habitat at two additional snail kite nests located near Harney Pond Canal. Both nests were located near the edge of a cattail stand adjacent to lily and open water foraging habitat. This type of detailed analysis is proving useful in understanding the dynamics and success potential of snail kite nesting and foraging activities on Lake Okeechobee.

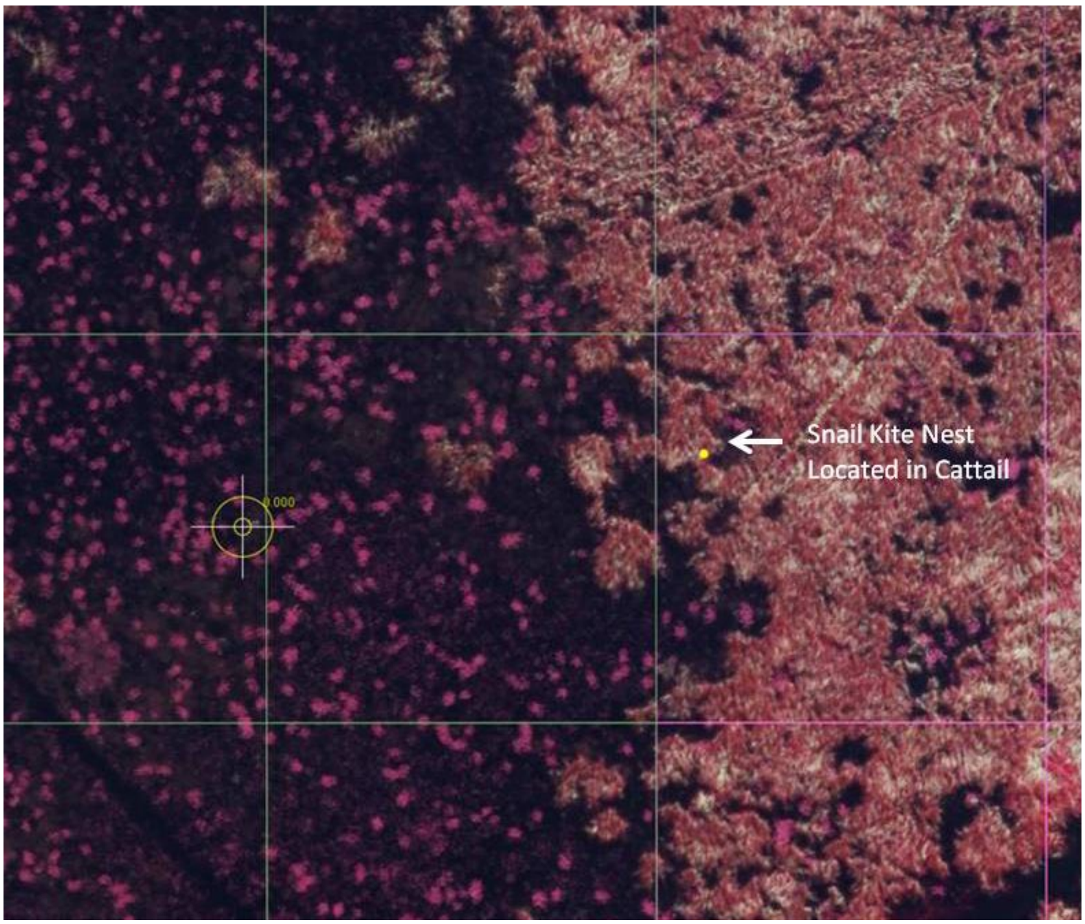


Figure 8-23. Color infrared image of a small area in Lake Okeechobee's northwest marsh near Harney Pond. The location of a snail kite nest (yellow dot) that was built in cattail is also noted. For spatial reference, each grid is one hectare (2.47 acres).

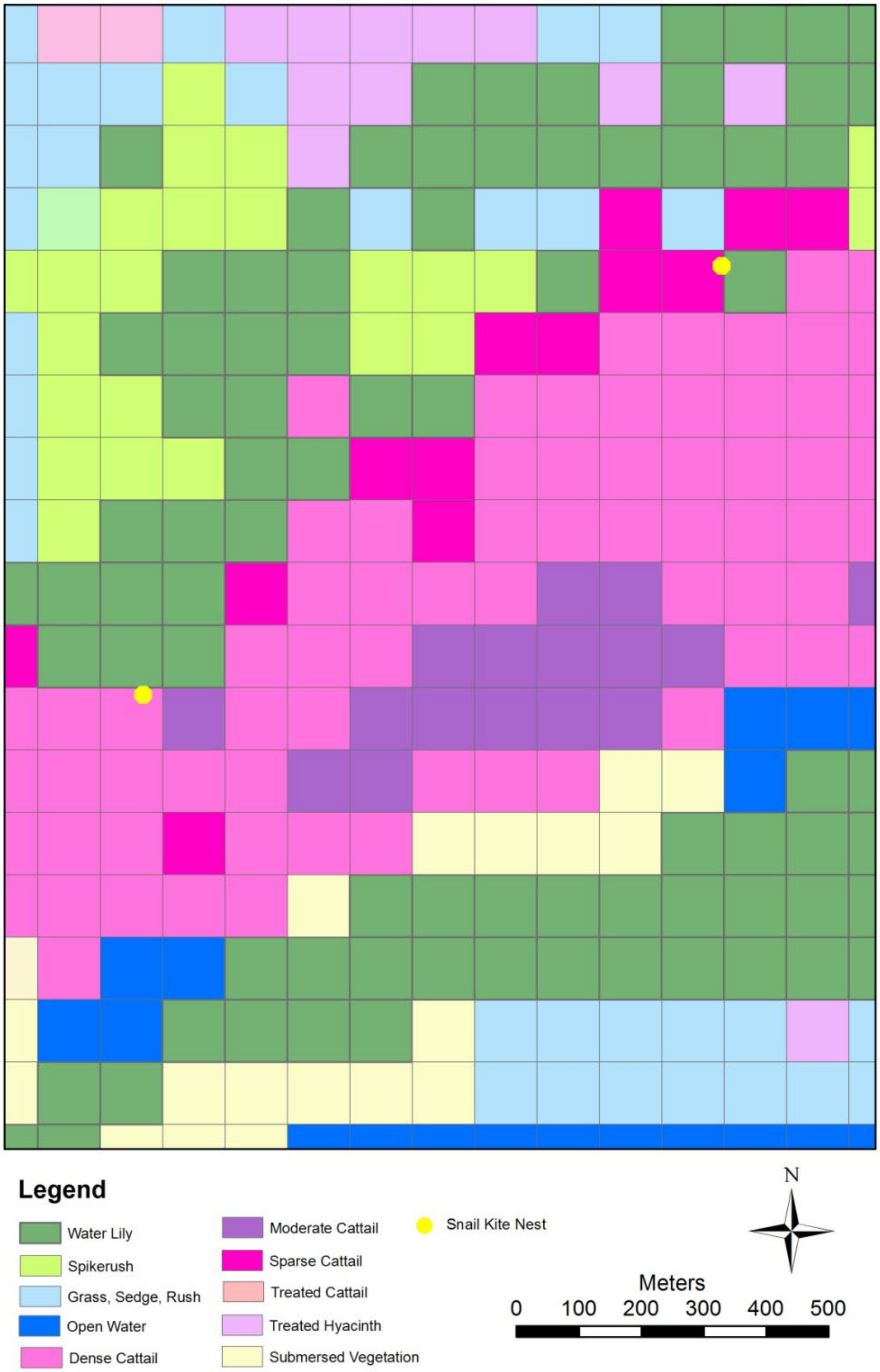


Figure 8-24. A small section of Lake Okeechobee's northwest marsh showing the dominant plant communities that provide nesting and foraging habitat at two snail kite nest sites near Harney Pond.

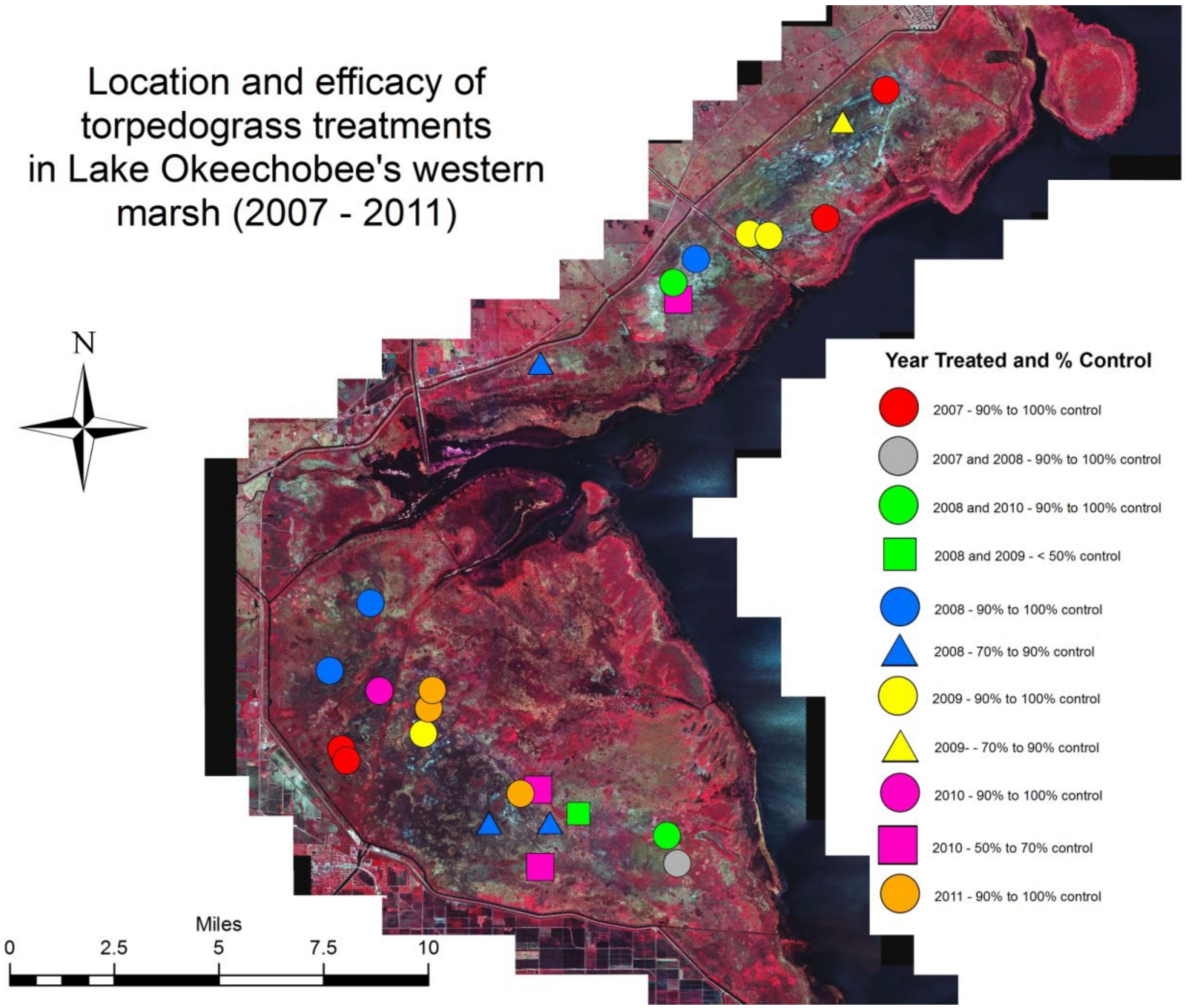
Exotic Species Control Program

The Lake Okeechobee Exotic Species Control Program identifies exotic species that threaten native flora and fauna within the Lake Okeechobee Watershed and develops and implements measures to protect native species from invasives. Exotic plants and animals identified as threatening native species require management, or in the case of some animal species, monitoring, to maintain awareness of possible future problems.

The program is designed to protect threatened native habitat in Lake Okeechobee and to restore areas of the marsh that have been impacted by undesirable species. Torpedograss is the most common emergent exotic plant in the lake's marsh and extensive efforts to reduce its coverage are ongoing. An evaluation of treatment efficacy indicated that many of the treatments provided excellent torpedograss control (90–100 percent), some for as long as five years following a single or in some instances multiple treatments. Of the 24 treatment sites evaluated, control was rated as 90 percent or greater at 16 locations (**Figure 8-25**).

During theWY2012, nearly 5,300 acres of torpedograss were treated in the lake's western marsh. Without the treatments, dense monocultures of torpedograss covering thousands of acres would be common in the upper elevation regions of the marsh. Although torpedograss is still present in many areas its coverage has been decreased dramatically. Native plant communities have colonized some of the treated sites and monthly wading bird surveys conducted in 2012 documented many birds foraging in shallow open water areas previously impacted by torpedograss

The floating exotic plants water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*), along with tropical watergrass, common reed (*Phragmites australis*), wild taro (*Colocasia esculenta*), West Indian marsh grass, melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), and cattail also were targets of the vegetation management program during the past year. Combined, the District treated more than 7,700 ac of vegetation in Lake Okeechobee western marsh and the USACE treated more than 6,700 ac of floating exotic plants (**Figure 8-26**).



1153 **Figure 8-25.** Location and efficacy of torpedograss treatments in Lake Okeechobee's western marsh. Colors indicate the
1154 year(s) of treatment and the symbols indicate treatment efficacy evaluated as percent control.

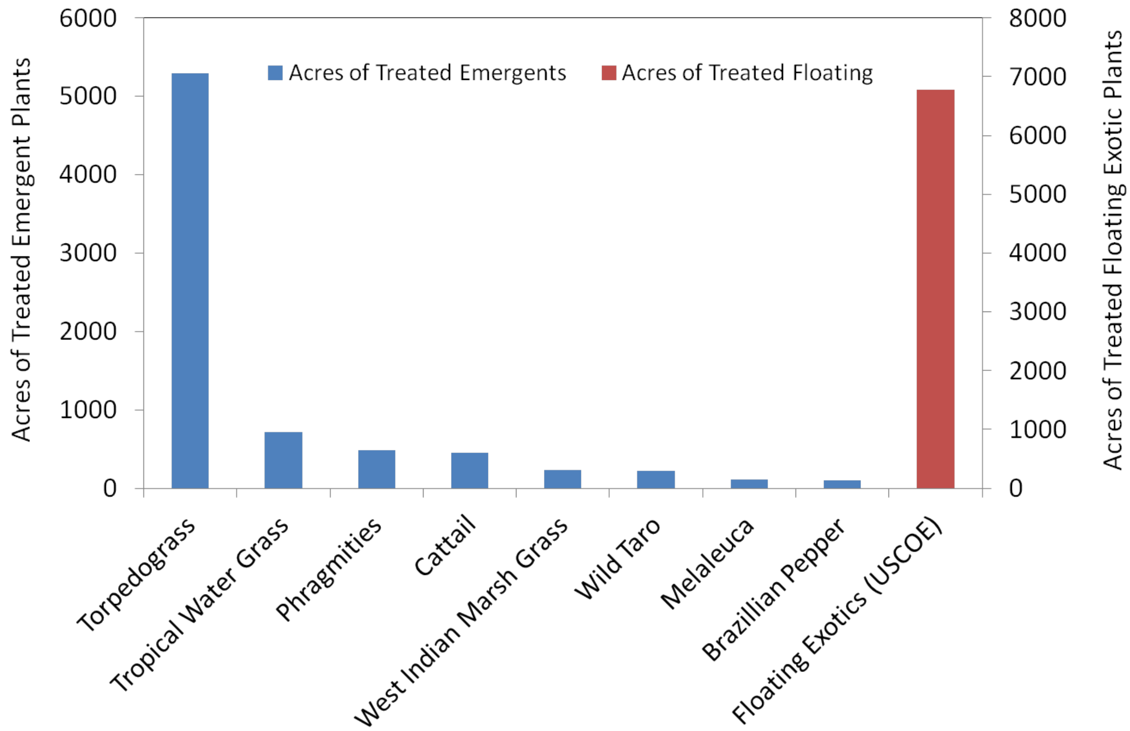


Figure 8-26. Number of acres of the most commonly treated (greater than 100 acres) plants in Lake Okeechobee during WY2012. The emergent vegetation (blue bars) was treated by SFWMD contractors and the floating exotic plants water hyacinth and water lettuce (red bar) were treated by contractors to the United States Army Corps of Engineers (USACE).

PHYTOPLANKTON

Routine Plankton Monitoring

Routine plankton monitoring, as reported in previous SFERs, continues although with some potential modifications. However, due to budgetary constraints in the two previous years, sample taxonomic and biovolume measurements were delayed and although funding has now allowed us to catch up with much of the sample backlog, at this writing the resultant data has not been sufficiently analyzed for reporting purposes. Updated plankton data will therefore be presented in the 2014 SFER.

Algal Blooms and Toxins

Algal biomass of bloom-forming blue-green algae and their associated toxins have been monitored on a monthly basis at nine nearshore sites since May 2004. In May 2011, this sampling effort was combined with the long-term water quality monitoring sampling effort and six of the nine algal bloom monitoring sites were relocated to nearby water quality monitoring sites (**Figure 8-27**). Three sites were dropped because there were no corresponding water quality sites nearby. Combining these two projects into one project resulted in more consistent data collection and reporting since the algal bloom and toxin data are now a subset of the water quality data instead of a separate sampling effort. An additional benefit to this sampling optimization is that it provides a substantial cost savings in both labor and operating expenses with minimal impact to algal bloom and toxin assessment capabilities.

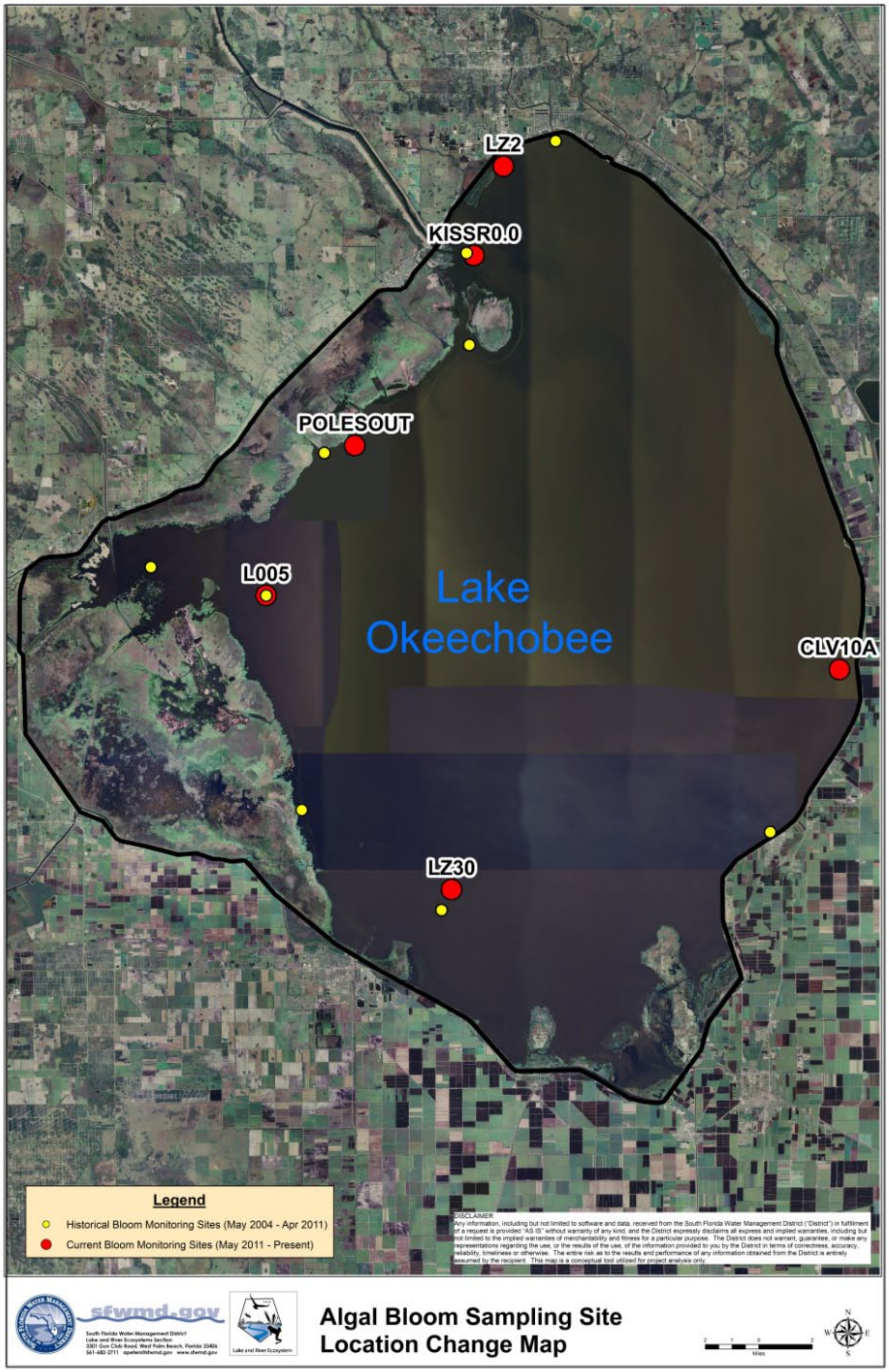


Figure 8-27. Map of algal bloom and microcystin sampling locations in Lake Okeechobee from May 2004 to April 2011 (yellow dots) and from May 2011 to April 2012 (red dots). Current monitoring locations are a subset of the long-term water quality monitoring network.

During WY2012, average Chl*a* concentrations did not exceed 40 micrograms per liter (µg/L), the value that defines algal bloom conditions (**Figure 8-28**). However, there were four instances where site and date specific Chl*a* concentrations were greater than 40 µg/L. The northern most site (LZ2) had bloom level Chl*a* concentrations in both July and August 2011 and a site along the northwestern shore (POLESOUT) had bloom levels in August 2011. The highest Chl*a* concentration during WY2012 was reported from the southernmost site (LZ30) in December 2011 where levels reached 75 µg/L. However, the corresponding algal toxin concentrations during WY2012 did not exceed the analytical limit of detection (0.2 ppb) even during these localized bloom events (**Figure 8-28**). Results indicate that although light conditions in the lake over the past two to three years have been favorable for surface bloom formation and an increase in bloom frequency was anticipated, only a few isolated and ephemeral incidents have occurred.

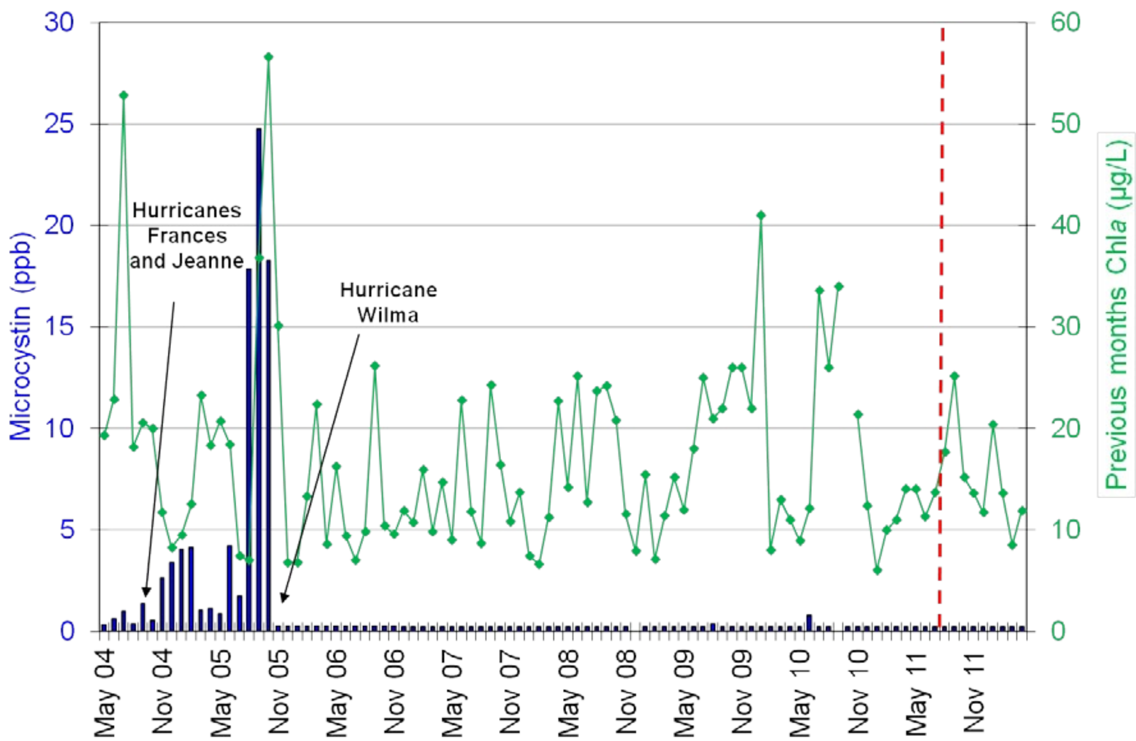


Figure 8-28. Average chlorophyll *a* (Chl*a*) and microcystin concentrations in Lake Okeechobee from May 2004 to April 2011 (9 sites) and from May 2011 to April 2012 (6 sites). Dashed red line indicates when sampling locations changed. A Chl*a* concentration of greater than 40 micrograms per liter (µg/L) indicates bloom conditions. No samples were collected in September 2010 due to inclement weather.

Periphyton

Periphyton is an important food source for herbivorous macroinvertebrates and fish in Lake Okeechobee (Havens et al., 1996; Steinman et al., 1997; Carrick and Steinman, 2001). In the nearshore region of the lake, periphyton also may compete with phytoplankton for nutrients when periphyton biomass is high, indirectly limiting phytoplankton growth (Phlips et al., 1993; Havens et al., 1996; Rodusky et al., 2001).

The most recent periphyton monitoring on Lake Okeechobee started in August 2002. Monitoring was suspended from spring 2006 to fall 2007 because of the loss of most SAV and emergent plants in the nearshore region following the passage of Hurricanes Frances, Jeanne, and Wilma during 2004–2005. Monitoring recommenced in October 2007 and continued until September 2010, at which time it was suspended because of budgetary constraints. Epiphytic (algae that grows on plant stems and leaves) monitoring recommenced in October 2011 and spring sampling was conducted in March–April 2012. Sampling and laboratory methods and site locations for 2002–2006 were reported in the 2010 SFER – Volume I, Chapter 10 and Rodusky (2010), while the most recent sites are shown in **Figure 8-29**.

The objective of this study was to examine periphyton biovolume, biomass, community structure, and nutrient storage dynamics under the highly variable lake conditions that occurred during the study period. The objective of the fall 2011 and spring 2012 monitoring was to collect additional epiphytic data from hydrilla, bulrush, and tape grass, since limited data existed for hydrilla and tape grass, and bulrush was not observed in the southern nearshore region of the lake between spring 2006 and spring 2010. During this reporting period, tape grass in the northern portion of the Lake Okeechobee nearshore region has reestablished in the southern fringe of the area where it previously was dominant, so spring 2012 sampling included two tape grass sites. Conversely, hydrilla in Fisheating Bay was substantially reduced, probably as a result of control efforts for the emergent exotic tropical watergrass. Hydrilla disappeared from sites WHydr 2 and 3 by the spring 2012 sampling period. Epipelic sampling has not resumed, since a sufficient number of samples have been collected to evaluate productivity and nutrient storage while Lake Okeechobee water levels have been within the ecologically desired stage envelope or lower, concurrent with a general lack of large-scale weather-related disturbance events. The monitoring plan details, epiphytic and epipelic biovolume, biomass and nutrient content data, and hypothesized relationships between periphyton abundance (as both biovolume and biomass) and various environmental factors were presented in the 2012 SFER – Volume I, Chapter 8.

Since 2010, epiphytic biomass during this reporting period has been lower, although samples were collected later in fall 2011 than when sample collection has typically occurred. There also was some seasonality observed, wherein fall 2011 biomass was generally higher than it was during spring 2012. The highest biomass was documented on musk grass during fall 2011, while the lowest was on bulrush during spring 2012. The general trend of recently higher epiphytic biomass is illustrated for musk grass and bulrush in **Figure 8-30** and for hydrilla and tape grass in **Figure 8-31**. There were no epiphyte data for musk grass in fall 2004, nor for bulrush for fall 2008 (north and west), fall 2011, and spring 2012 (north) and for 2008–2010 (south) because of seasonal senescence of host plants, replacement of one taxon with another (e.g., cattail replacing bulrush near King’s Bar) or a delay in recovery of host plants after the hurricanes in 2004 and 2005. With an increase in SAV and emergent plant coverage since 2007, there has been a general increase in epiphytic biomass. For this reporting period, the highest epiphytic biomass was observed on musk grass [2,901 milligrams per grams of host dry weight (mg/g dw)] near Observation Island and tape grass near King’s Bar (211 mg/g dw). The amount of mean epiphytic biomass per unit host plant dry weight between 2008–2010 is very similar to that reported during 1989–1991, when lake stage was lower than the long-term average (Zimba, 1995).

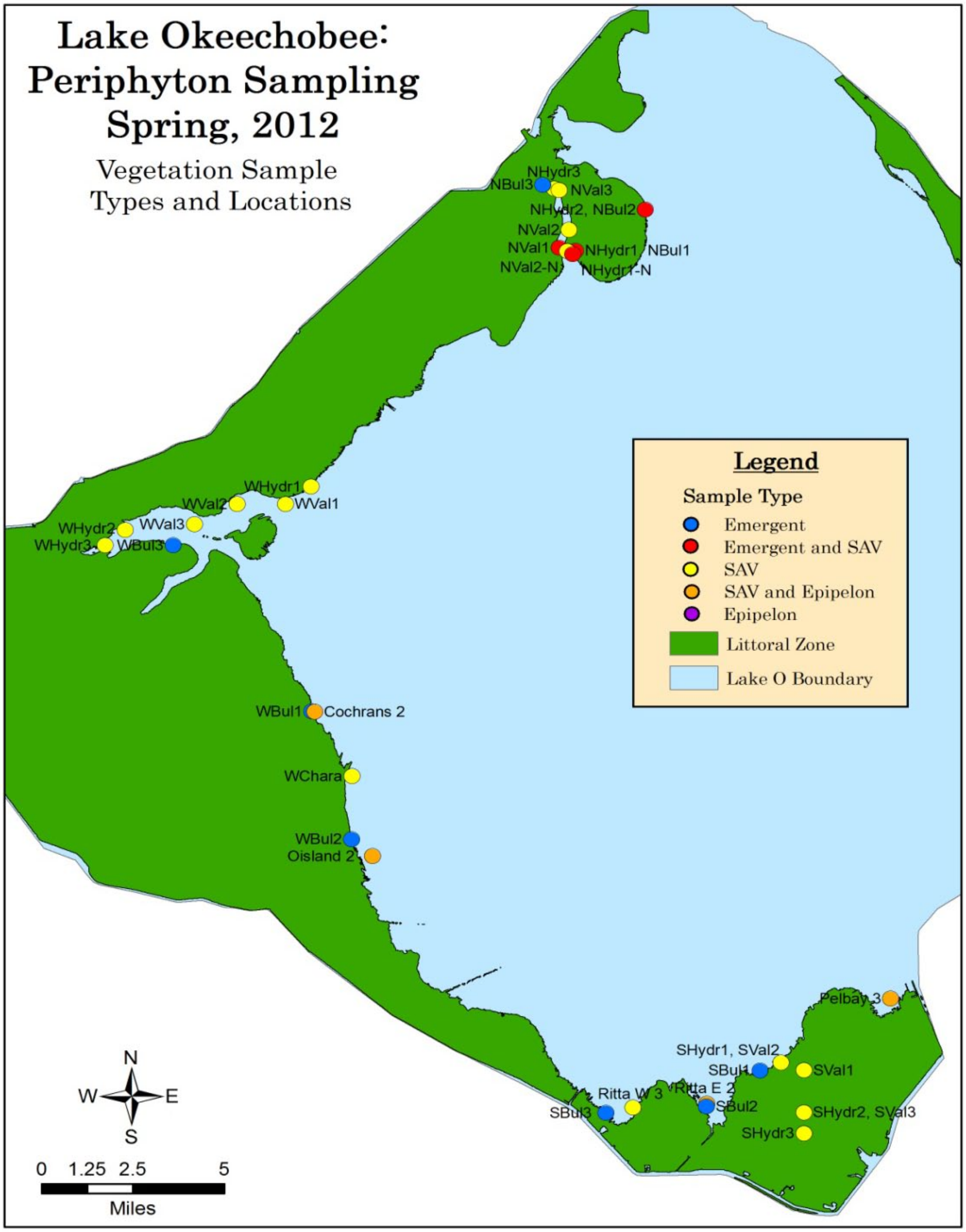


Figure 8-29. Nearshore epiphytic sites for fall 2011 and spring 2012 monitoring periods. Littoral zone sites in the south that used to be dominated by SAV beds are now dominated by emergent plants.

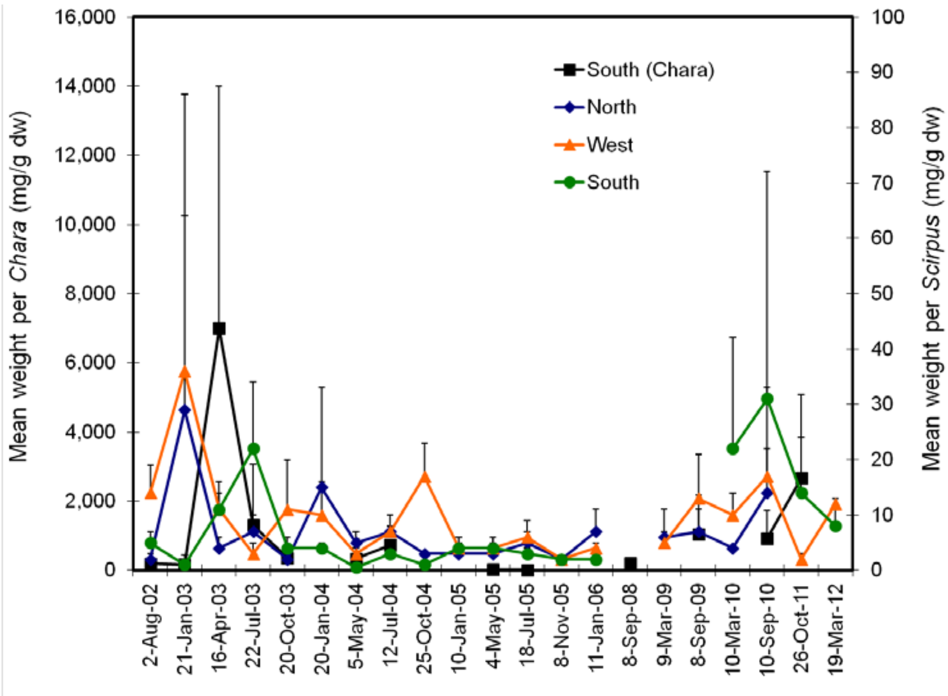


Figure 8-30. Nearshore musk grass (*Chara*) and bulrush (*Scirpus*) epiphytic mean abundances (+1 standard deviation) in Lake Okeechobee as milligrams per gram host dry weight (mg/g dw).

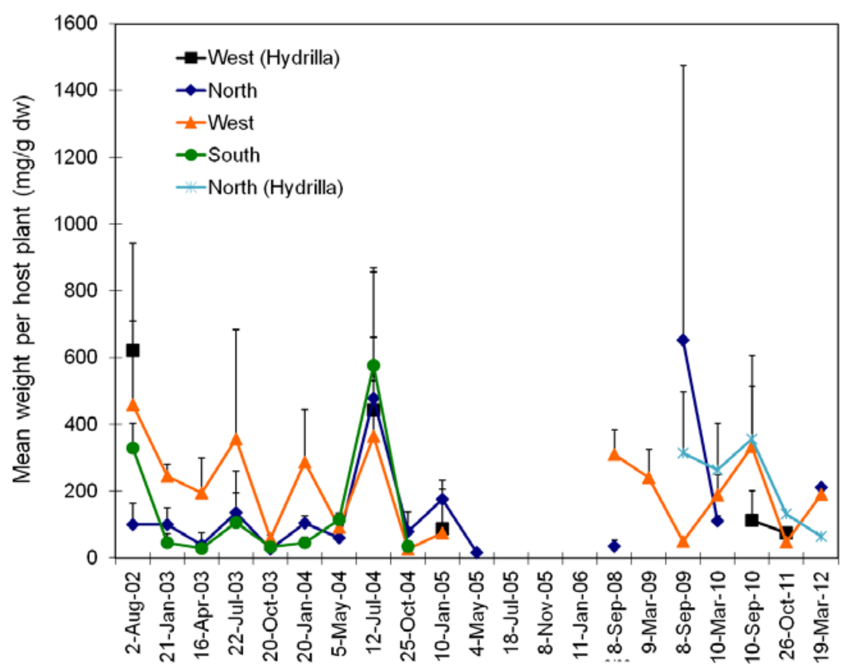


Figure 8-31. Nearshore hydrilla (*Hydrilla*) and tape grass (*Vallisneria*) epiphytic mean abundances (+1 standard deviation) in Lake Okeechobee.

Periphyton abundance (as biovolumes) data from fall 2011 and spring 2012 has not yet been determined from the taxonomic samples. Prior to 2008, periphyton abundance was generally less than in 1995 (Carrick and Steinman, 2001; Rodusky, 2010), while mean epiphytic abundance has been higher between 2008 and 2010 on all plant hosts, except for hydrilla in Fisheating Bay, where it has been similar to that in 2004 (**Figure 8-32**). Epiphytic biovolumes on bulrush have been approximately a magnitude of order lower relative to that on the SAV host taxa (**Figure 8-33**). Epiphytic biovolumes on cattail have only been determined since 2008, although the general pattern between 2008 and 2010 was that the epiphytes on cattail were similar to or half an order of magnitude higher than that on bulrush. In general, epiphytes on both emergent host taxa have been lower than on the SAV host taxa, the same pattern observed for epiphytic biomass during the 1989–1991 period (Zimba, 1995). Since 2002, both the epiphytic and epipelic communities on all host taxa have been dominated (greater than 80 percent) by diatoms.

Periphyton N, P, and carbon (C) mean storage concentrations have been variable since 2010. For P, N, and C, mean cell content was generally higher during fall 2011 when compared to both 2010 and spring 2012. The highest mean P, N, and C cell content was in bulrush-associated epiphytes in Fisheating Bay during fall 2011, while the lowest was on musk grass near Observation Island during the same sampling period. Total N:P ratios during this reporting period were little changed from those previously reported in the 2011 SFER – Volume I, Chapter 10 and continued to suggest strong N-limitation.

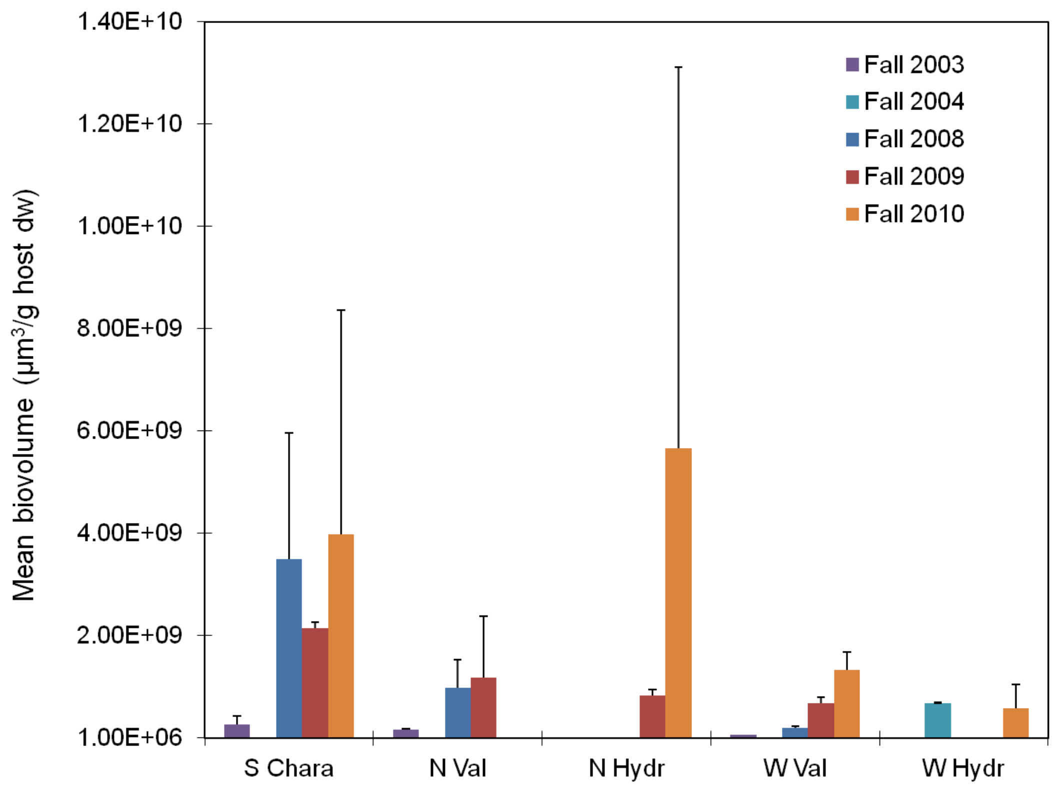


Figure 8-32. Nearshore musk grass (*Chara*), hydrilla (*Hydrilla*) and tape grass (*Vallisneria*) epiphytic mean biovolumes (+1 standard deviation) in Lake Okeechobee as cubic micrometers per gram host dry weight (μm^3/g dw).

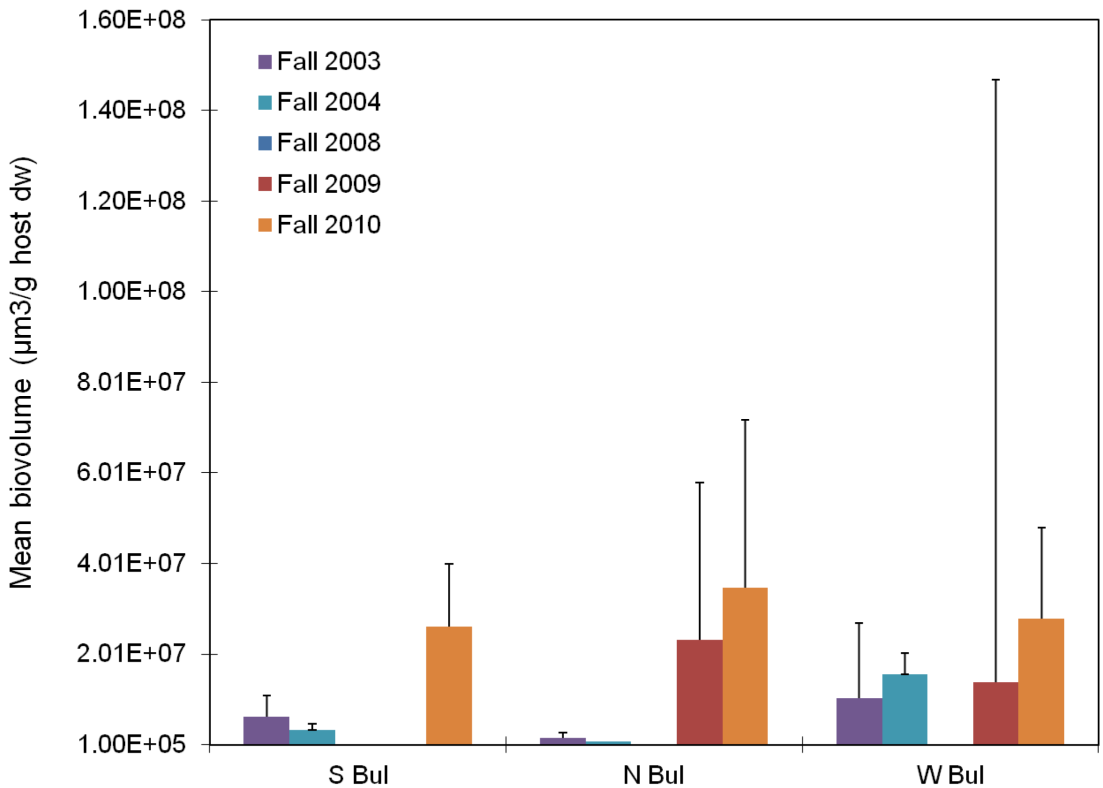


Figure 8-33. Nearshore bulrush epiphytic mean biovolumes (+1 standard deviation) in Lake Okeechobee. Note the difference in the y-axis scales for the two biovolume graphs (**Figures 8-32** and **8-33**).

In general, lake stage as it relates to light availability and host substrate areal coverage in the nearshore region appears to be the most influential factors affecting periphyton biomass, and the availability of suitable host substrate appears to be more influential than seasonally influenced factors. Thus, maximal periphyton abundance and nutrient storage may occur if the lake is more frequently within the desired stage range (12.5–15.5 ft NGVD) considered conducive to emergent plant and SAV growth. With the persistence of lower lake stages during the post-hurricane period, mean summertime total seasonal epiphytic biovolume has been greater relative to that during the pre-hurricane period. The trend in the amount of summer season mean epiphytic biovolume per amount of colonizable SAV appears to generally be positively associated with SAV areal coverage and negatively associated with lake stage (2012 SFER – Volume I, Chapter 8). Lower lake water levels and higher periphyton biomass and nutrient storage may be important in indirectly reducing the frequency of phytoplankton blooms via nutrient competition (Phlips et al., 1993; Havens et al., 1996; Rodusky et al., 2001). Maximizing SAV areal coverage and periphyton abundance in the nearshore region of Lake Okeechobee may be very important over the next decade, since P concentrations are in the range where shallow subtropical lakes can switch from SAV to phytoplankton dominance (Liboriussen and Jeppesen, 2006; Bécares et al. 2008; Yang et al. 2008, Rodusky, 2010). Thus, maintaining lower water levels along with continued reductions in watershed nutrient loading may be critical in preventing the nearshore region of the lake from switching to a phytoplankton dominated stable state.

MACROINVERTEBRATES

A three-year (August 2005–February 2008) baseline monitoring study of macroinvertebrates in the pelagic region of Lake Okeechobee was conducted by the FWC under contract to the District (Warren et al., 2008). Results were summarized in the 2010 SFER – Volume I, Chapter 10. As water quality in the lake improved over the study period and water levels declined, midges, segmented worms, Asian clams (*Corbicula fluminea*), and water mites increased. Based on taxonomic composition, densities, species richness, and diversity, macroinvertebrate communities in peat and sand sediments improved, which should enhance the lake's food web and increase recruitment of fish and other vertebrates that eat macroinvertebrates.

Since 2008, biannual sampling has been conducted by the FWC at the same nearshore and pelagic sites (Warren et al., 2008). Due to budgetary constraints, the preserved samples have been archived prior to sample processing and taxonomic identification steps and it is unlikely, given proposed monitoring reductions, that funding to analyze these samples will become available. While the macroinvertebrate community was shown to be recovering from impacts related to the hurricanes of 2004 and 2005, trends in this important ecosystem component since 2008 cannot be analyzed or reported.

FISH

Lake Okeechobee's fishery is monitored annually by the FWC. They use a standardized lake-wide electrofishing protocol to monitor the nearshore fishery and a lake-wide trawling protocol to monitor pelagic species.

Electrofishing

Lake-wide electrofishing conducted at 21 sites during fall 2011 resulted in the capture of 4,442 fish with a combined biomass of 904,547 grams. Fish abundance was reduced in 2011 compared to 2010, but was greater than the abundance observed in 2009. Fish biomass was the highest recorded during the six-year period of record; up 84 percent when compared to 2005 (**Figure 8-34**). Thirty-four fish species were represented in the 2011 catch. Five dominant species (more than 5 percent composition) collectively comprised 68 percent of the catch by number and were, in order of abundance: bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), inland silverside (*Menidia beryllina*), and gizzard shad (*Dorosoma cepedianum*). Seven species collectively comprised 86 percent of the catch by weight and were, in order of biomass: largemouth bass, striped mullet (*Mugil cephalus*), bluegill, Florida gar (*Lepisosteus platyrhincus*), bowfin (*Amia calva*), redear sunfish, and channel catfish (*Ictalurus punctatus*).

Comparison of lake-wide electrofishing data indicated changes in community structure expressed as changes in the proportions of select prey and piscivorous species (**Figure 8-35**). Gizzard shad, threadfin shad (*Dorosoma petenense*), and eastern mosquito fish (*Gambusia holbrooki*) constituted a large percentage of the total catch in 2008 while the percentage of piscivorous fish was generally low. As the percentage of several forage species declined in 2009, 2010, and 2011, the percentage of the population consisting of bluegill and redear sunfish increased (**Figure 8-36**).

In addition to fish abundance, the size and composition of the fish community can be evaluated using catch per unit effort (CPUE) data. From 2005 to 2010 there was an increasing trend in the numbers for several dominant species including bluegill, redear sunfish, and largemouth bass (**Figure 8-37**). A decrease in abundance of some species in 2011 was likely influenced by a record rain event during the sampling period, which resulted in a 2.5 ft increase in lake stage during a one-month period of time.

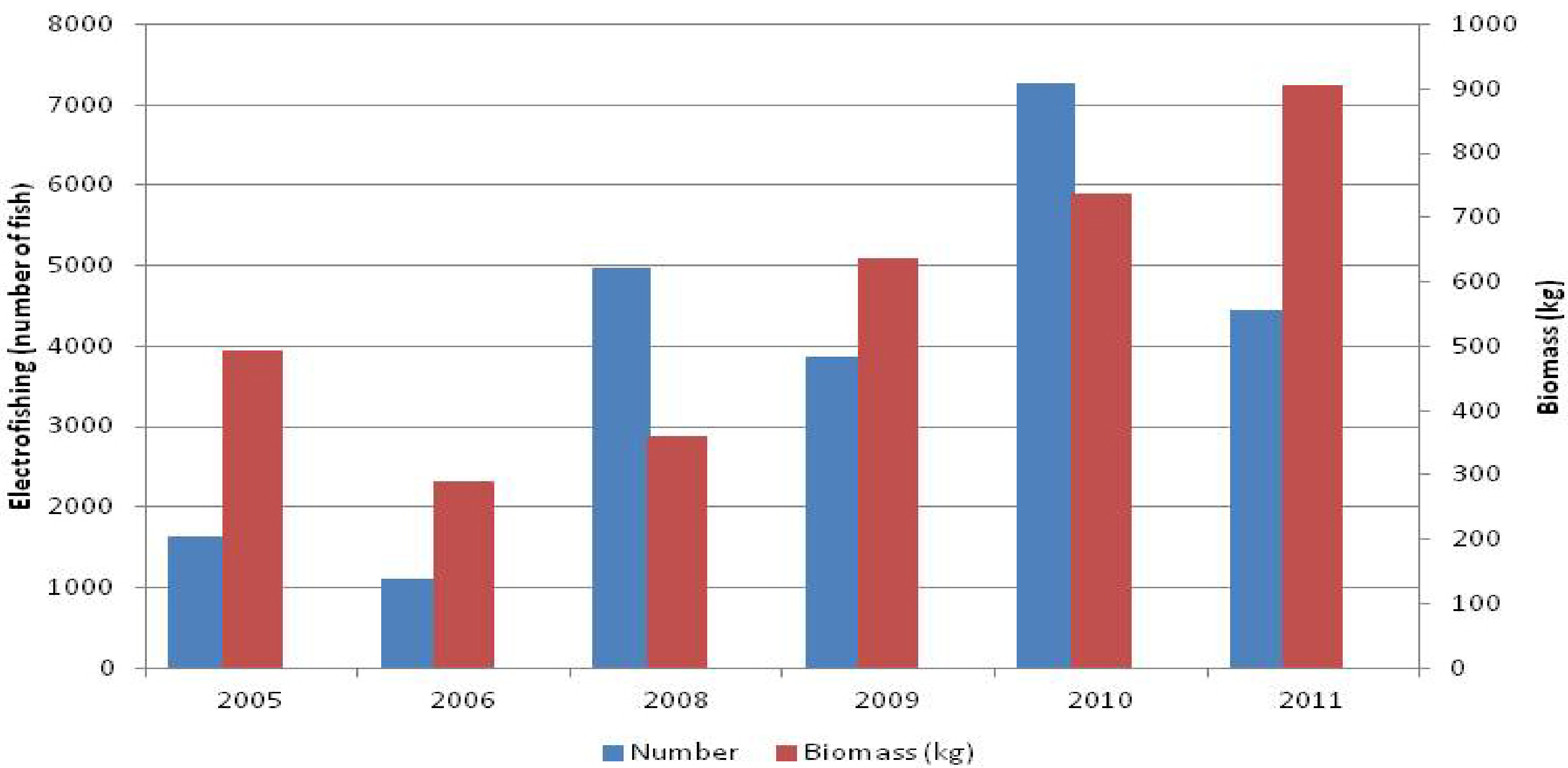


Figure 8-34. Comparison of lake-wide electrofishing data indicating total biomass in kilograms (kg) (red) and the total number of fish (blue) collected during fall 2005–fall 2011.

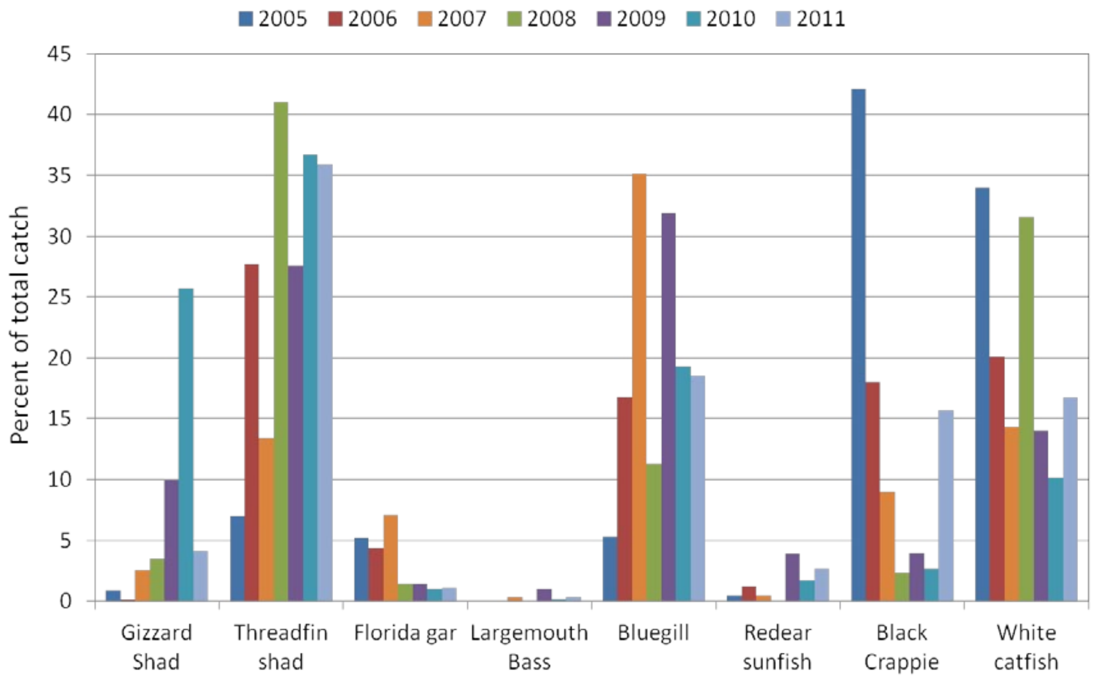


Figure 8-35. Percent of total catch of selected prey and piscivorous species collected by electrofishing during fall 2005–fall 2011.

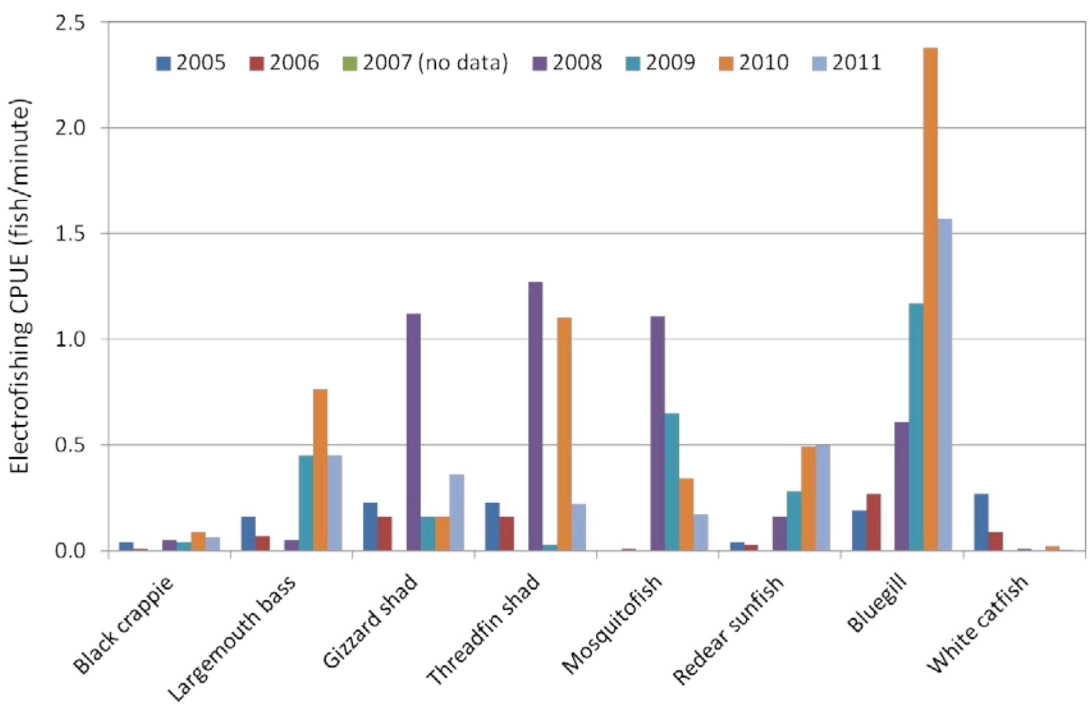


Figure 8-36. Electrofishing catch per unit effort (CPUE) values for 2005–2011. Much of the increase in the 2010 fish population was attributed to increases in largemouth bass, redear sunfish, threadfin shad, and bluegill. The decrease in abundance of most species other than gizzard shad in 2011 was likely due to a record rainfall event that occurred during the sampling period.

Trawling

Lake-wide trawl sampling resulted in the capture of 3,281 fish with a combined biomass of 270,119 grams (**Figure 8-37**). Fourteen fish species were represented in the catch. Four species collectively comprised 87 percent of the catch by number and included in order of abundance: threadfin shad, bluegill, white catfish (*Ameiurus catus*) and black crappie (*Pomoxis nigromaculatus)*. Seven species collectively comprised 94 percent of the catch by weight and were, in order of biomass: white catfish, bluegill, black crappie, Florida gar, channel catfish, threadfin shad, and redear sunfish.

Fish abundance and biomass in 2011 were reduced by 76 and 59 percent, respectively, when compared to 2010. This was partially due to a reduction in gizzard shad abundance, which had reached a record value in 2010. When compared to 2005, the total catch and biomass in 2011 increased by 187 and 216 percent, respectively (**Figure 8-37**).

Threadfin shad, bluegill, and white catfish consistently accounted for much of the total catch during the six-year period (**Figure 8-38**). Black crappie comprised more than 40 percent of the total catch in 2005 but declined to less than 5 percent of the catch in 2008, 2009, and 2010. The black crappie population recovered somewhat in 2011 and accounted for 16 percent of the total catch (**Figure 8-38**).

The abundance of gizzard shad, threadfin shad, bluegill, and white catfish reached their highest density in 2010 then declined to a more historic average density in 2011 (**Figure 8-39**). The density of black crappie declined sharply for several years after 2006. However, the density of black crappie increased in 2011 and was similar to the densities recorded in 2005 and 2006.

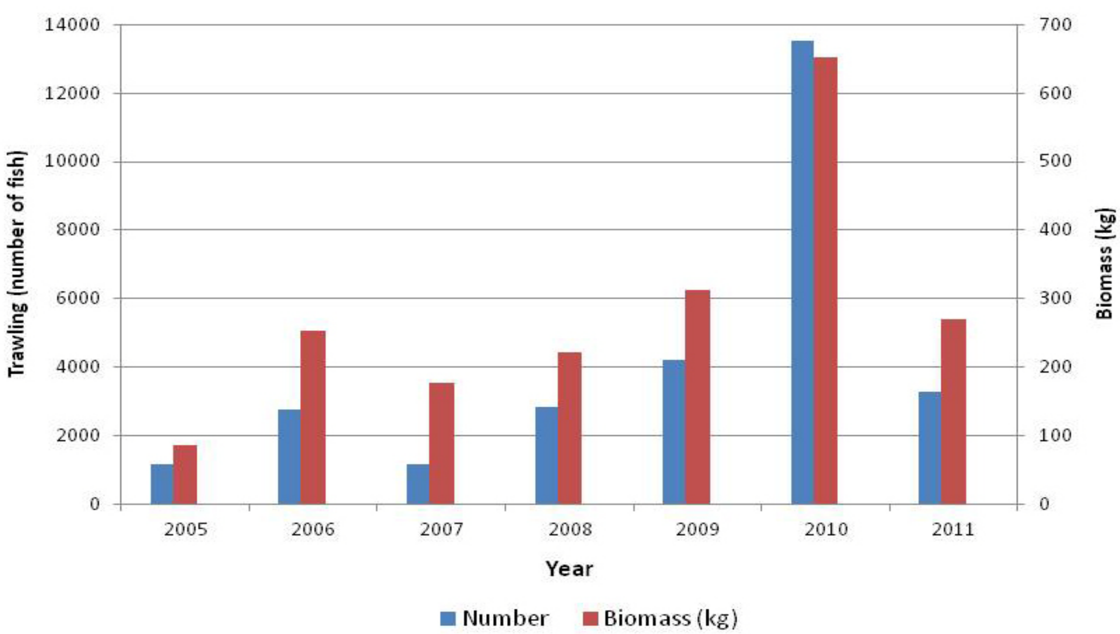


Figure 8-37. Comparison of lake-wide trawling data indicating the total number of fish (blue) and total biomass (red) collected during fall 2005–fall 2011.

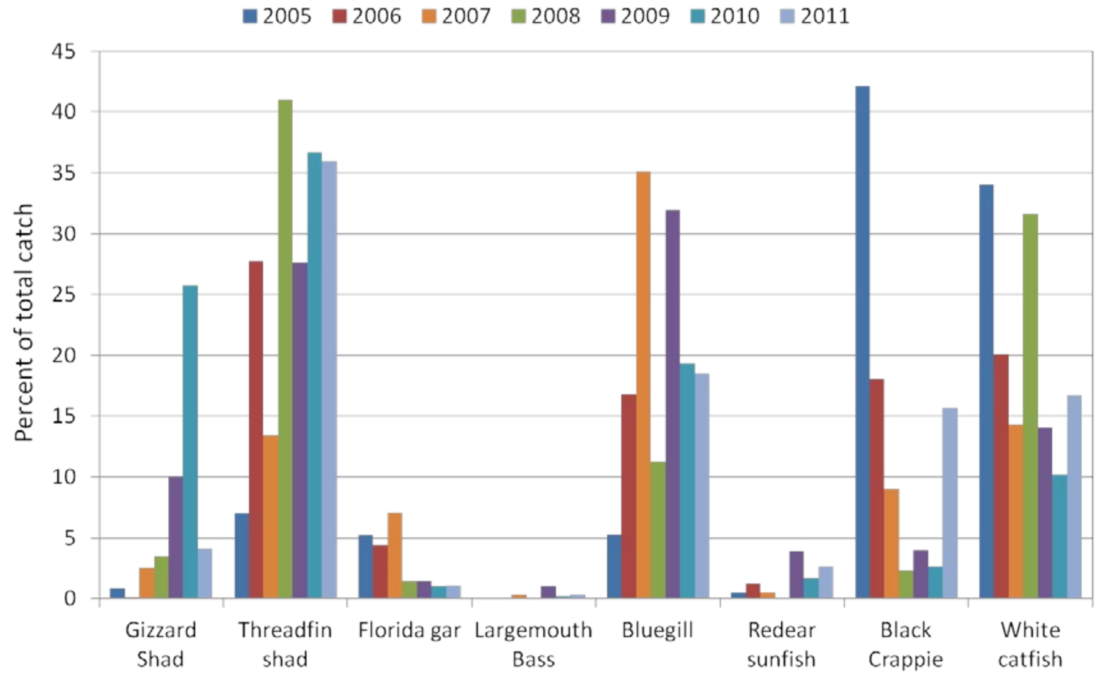


Figure 8-38. Percent of total catch of selected prey and piscivorous species collected by trawling in the pelagic region of the lake during fall 2005–fall 2011.

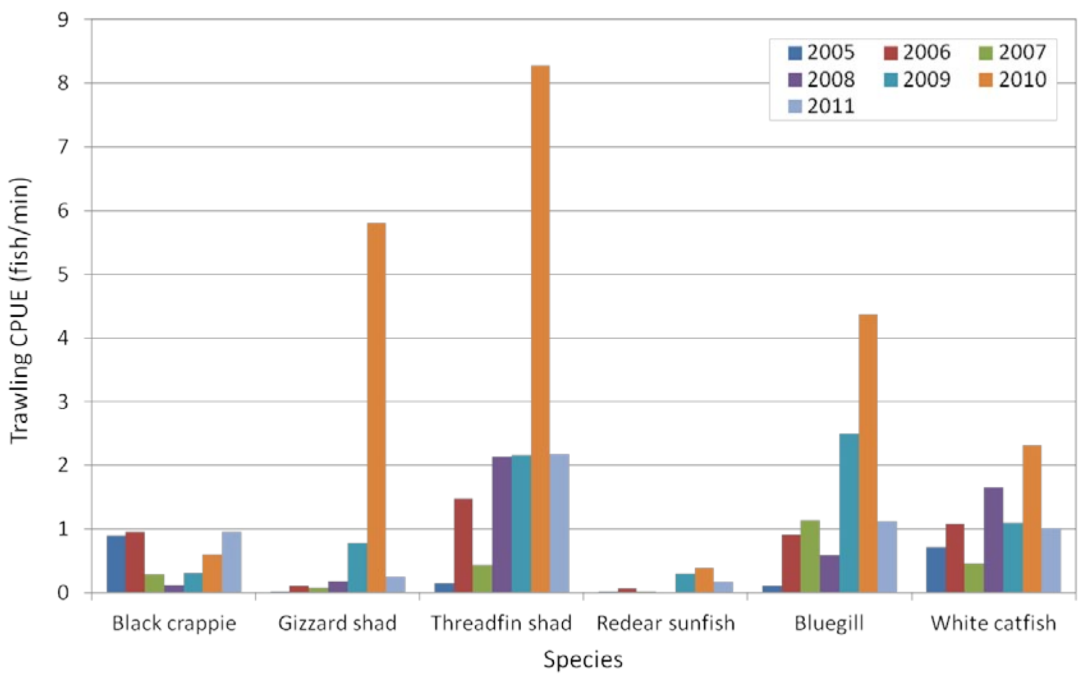


Figure 8-39. Trawling CPUE values for 2005–2011. Following a large increase in gizzard shad, threadfin shad, bluegill, and white catfish abundance in 2010, densities of these species declined in 2011.

Sport Fish Recovery

The largemouth bass and black crappie populations were depressed due to high lake levels and the subsequent loss of habitat and primary and secondary production following hurricane disturbances in 2004 and 2005. The catch rates for largemouth bass in 2005 were the second lowest observed since the monitoring program was initiated in 1992. Length frequency plots indicate that very little recruitment of young of the year largemouth bass occurred that year. The black crappie population also experienced a significant decline. Only five adult fish [greater than 200 millimeters (mm) in length] were collected in 2005. The decline in the black crappie population exceeded 99 percent when compared to the average annual catch of more than 2,000 fish in 1988–1991. A similar decline (97 percent) also was reported for threadfin shad; a primary forage fish for adult black crappie in Lake Okeechobee. The populations of largemouth bass and black crappie have recently showed signs of recovery (**Figure 8-40**). Largemouth bass produced consecutive strong year classes in 2009, 2010, and 2011, and black crappie produced a strong year class in 2010 and 2011 (**Figure 8-40**). The largemouth bass population decrease from 2010 to 2011 but still was comparable to the 2009 population. Some of the recorded decline likely was due to fish moving after a large rain event that occurred during the sampling period.

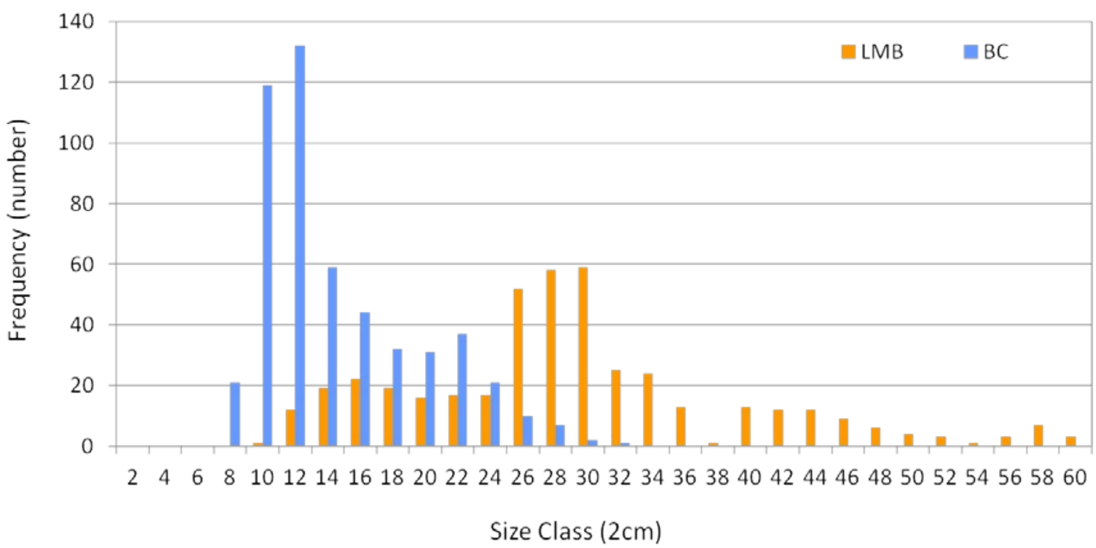


Figure 8-40. Length distribution per 2-centimeter (cm) size class for largemouth bass (LMB) (orange) (n=428) collected in Fiscal Years 2011–2012 (FY2011–FY2012) (October 1, 2010–September 30, 2012) lake-wide electrofishing samples and black crappie (BC) (blue) (n=516) collected in FY2011–FY2012 lake-wide trawling samples.

HERPETOFAUNA

Reptiles and amphibians (herpetofauna) are often overlooked components of aquatic ecosystems. The total biomass of these animals can, in many areas, exceed that of all other vertebrates combined and herpetofauna can serve as excellent indicators of environmental conditions. Elucidating the influence of these predators within the larger food web, both as consumers and as prey, is critical to developing an understanding of the effects of operational decisions and stochastic events on the Lake Okeechobee ecosystem. Herpetofauna are sensitive to many of the same factors that affect other native species, including extreme water levels, deleterious changes in water quality, rapid water level changes, and the introduction of exotic species.

There has never been a sustained and comprehensive herpetofaunal inventory of the Lake Okeechobee marsh; the only information available being a single study undertaken more than 10 years ago (USACE, 1999). In an attempt to expand on this initial work, a survey study was begun to describe the herpetofauna of the littoral zone by monitoring populations along elevation gradients and in differing marsh habitats. The three objectives of this study were to (1) provide a species list of native and introduced species for the Lake Okeechobee marsh, (2) estimate species diversity and abundance in various habitats within the marsh, and (3) track seasonal activity patterns and behavioral changes brought about by water level fluctuations.

The first herpetofauna survey began in January 2011 along three transects (**Figure 8-41**). These transects captured different habitat types along a depth gradient, running from the shoreline at the base of the Herbert Hoover Dike lakeward to the bulrush/cattail wall. On each transect, herpetofauna were measured at three sites along the gradient using methods developed during a preliminary study in summer and fall during 2009 and 2010, which determined the optimal methods of sampling to use at each site based on hydrologic conditions. During normal water levels, a combination of call surveys, fyke nets, pyramid traps, and funnel traps were used. Under dry conditions, when aquatic sampling was not possible but it was still possible to access a site, call surveys, artificial cover, and funnel traps set in drift-fence arrays were used.

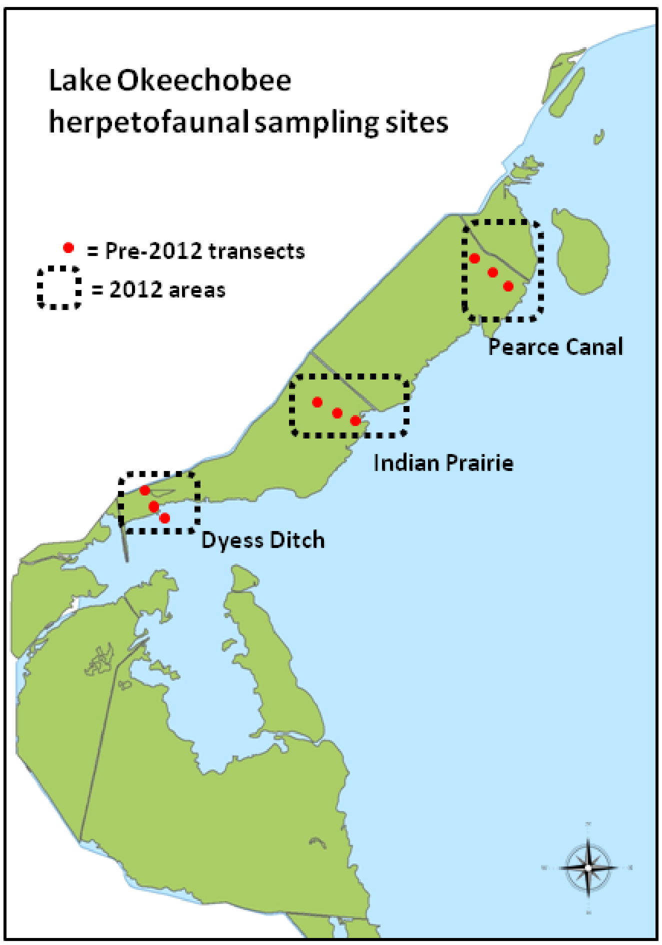


Figure 8-41. Sampling locations in the northwestern marsh of Lake Okeechobee. Preliminary transect sites are marked in red. Dashed lines represent FY2012 sampling areas.

In 2011, low catch rates and persistent dry conditions in the marsh prompted two major changes to the sampling protocol. First, since experimental tilling and disking operations in spring 2008 turned up large numbers of herpetofauna (E. Crawford, SFWMD, personal communication), suggesting that a significant portion of the herpetofaunal biomass might be estivating, it was decided to excavate two dry marsh sites during the summer wet season to test this hypothesis. Two sites were excavated in July 2011. Both locations (near Indian Prairie and Pearce Canal) were chosen in similar vegetation [knotweed (*Polygonum* spp.) and grass species] that had been dry for at least six months. A 5-square meters (m^2) area was excavated approximately 2 cm at a time until a depth of 50 cm was reached. The short duration of this study limited its results. However two musk turtles (*Sternotherus odoratus*) were found as well as ten native Florida apple snails (*Pomacea paludosa*). These ten snails represent the only individuals of this species found estivating in the wild as far as we can determine.

Second, since continued low lake stages have rendered the depth gradient approach unachievable, beginning in November 2011, trapping locations were chosen based on dominant vegetation type instead of the predetermined linear transect. Trapping is conducted monthly in the same three major areas of the western marsh (Dyess Ditch in north Fisheating Bay, Indian Prairie, and Pearce Canal west of King's Bar) (**Figure 8-41**). In each area trapping arrays are placed at sites dominated by spikerush (*Eleocharis cellulosa*), floating-leaved plants (predominantly *Nuphar* and *Nymphaea* spp.), and knotweed. As the marsh flora continues to change with varying water levels and colonization, the location of each site may change from month to month. We can now follow the optimum sampling depth of 30–50 cm regardless of changes in the marsh, thus allowing for more aquatic sampling (greater number of captures than on land) on more days. Sampling arrays consist of two mini-fyke nets linked by a drift fence and supplemented by pyramid traps (**Figure 8-42**). On each sampling event, arrays are deployed and allowed to sit in place for 24 hours. All traps are then retrieved and captured animals identified. Sirens, amphiumas, and non-venomous snakes are measured (to the nearest centimeter), weighed (to the nearest gram) and released. Fish and invertebrates are identified to genus (where possible) and counted (numbers greater than 25 may be estimated). Water depth, frog calls, and environmental conditions are also noted.

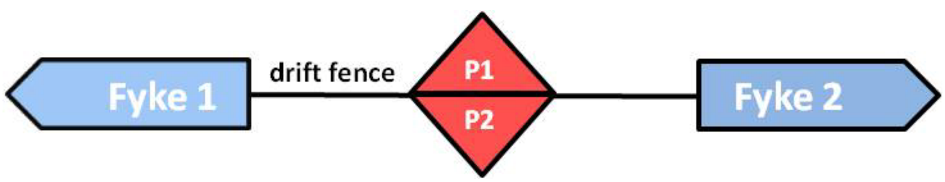


Figure 8-42. Trapping array setup. Two mini-fyke nets are linked with a drift fence. Herpetofauna encountering the drift fence move along it and into one of the nets. In the center are two pyramid traps, one with its openings at the surface and the second on the lake bottom.

Results

Sampling is still in progress; however some trends are becoming apparent. The arrays are capturing many organisms besides amphibians and reptiles. By far the most abundant (in number of individuals) species collected is the grass shrimp (*Palaemonetes paludosus*) followed by the eastern mosquitofish and bluefin killifish (*Lucania goodei*). Fish are found in the greatest number and biomass. Most of these species are at the primary or secondary consumer level.

Captured herpetofauna are dominated (in both numbers and biomass) by greater sirens (*Siren lacertina*), followed by frogs (order *Anura*). Few snakes or turtles have been caught since the change in sampling protocol, however summer sampling, which is expected to have greater trapping success based on previous data and the nature of herpetofaunal physiology, is just beginning. Herpetofauna as a whole (n = 52) is fairly evenly distributed between vegetative types, while Dyess Ditch sites have been approximately half as productive as those at Indian Prairie and Pearce Canal (0.6, 1.4, and 1.5 individuals per sampling effort, respectively) (**Figure 8-43**).

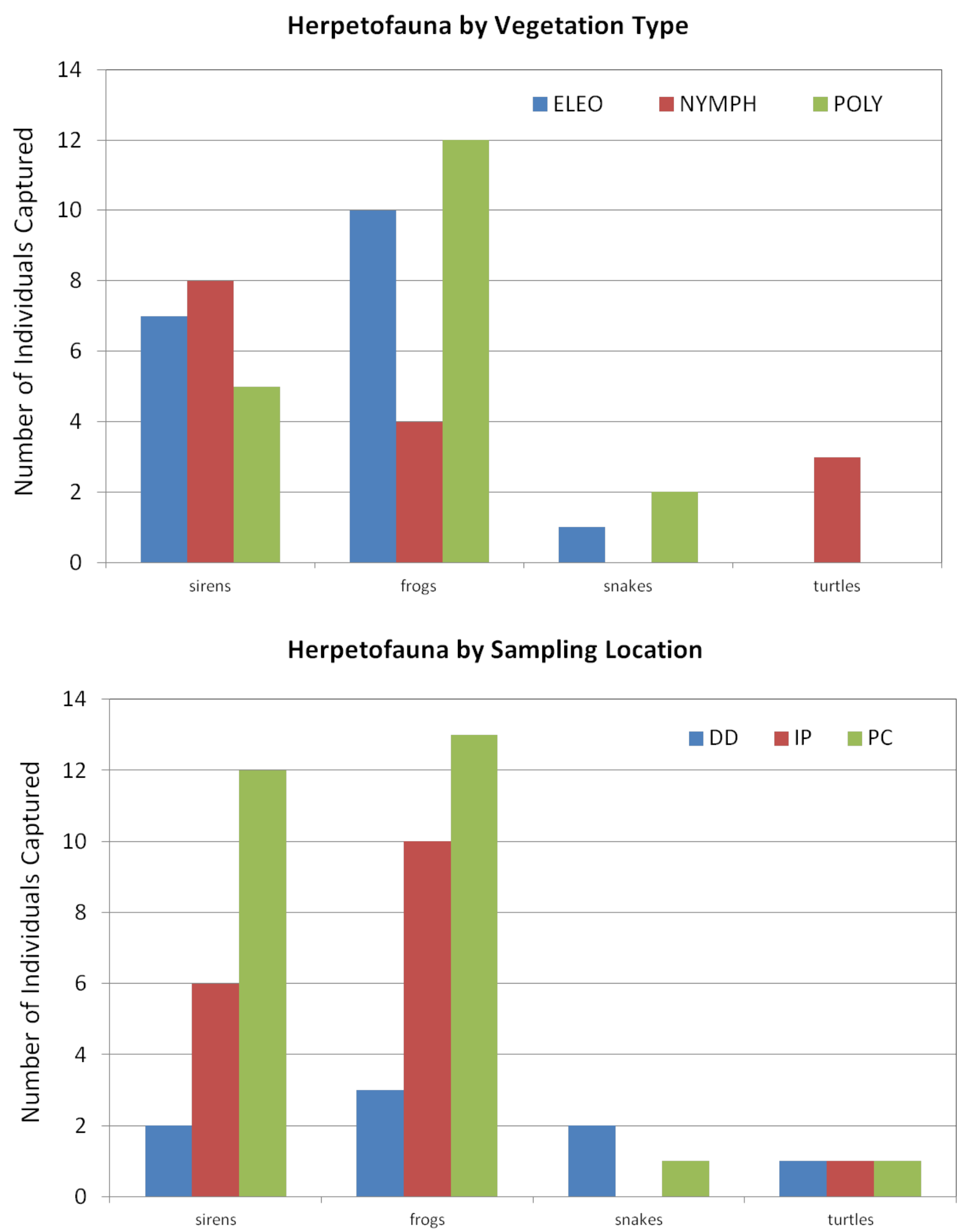


Figure 8-43. Herpetofauna capture distribution for the current study (November 2011–present) by vegetation type (top panel) and sampling location (bottom panel). [Note: DD = Dyess Ditch sites; IP = Indian Prairie sites; and PC = Pearce Canal sites.]

Fish show a similar trend for both vegetation and location, however fish species in knotweed, which has a far more dense and intricate matrix than either floating-leaved plants or spikerush beds, are almost exclusively small omnivores. This is similar to results encountered in a study comparing less dense and complex spikerush habitat and denser, more three-dimensionally complex torpedograss in Lake Okeechobee's western march (Rodusky et al., in press) (**Figure 8-44**). Trapping under the current protocol is planned to continue at a minimum through October 2012 to complete a full calendar year. The intention is to generate sufficient data points for statistical analysis on diversity as well as species abundance and distribution.

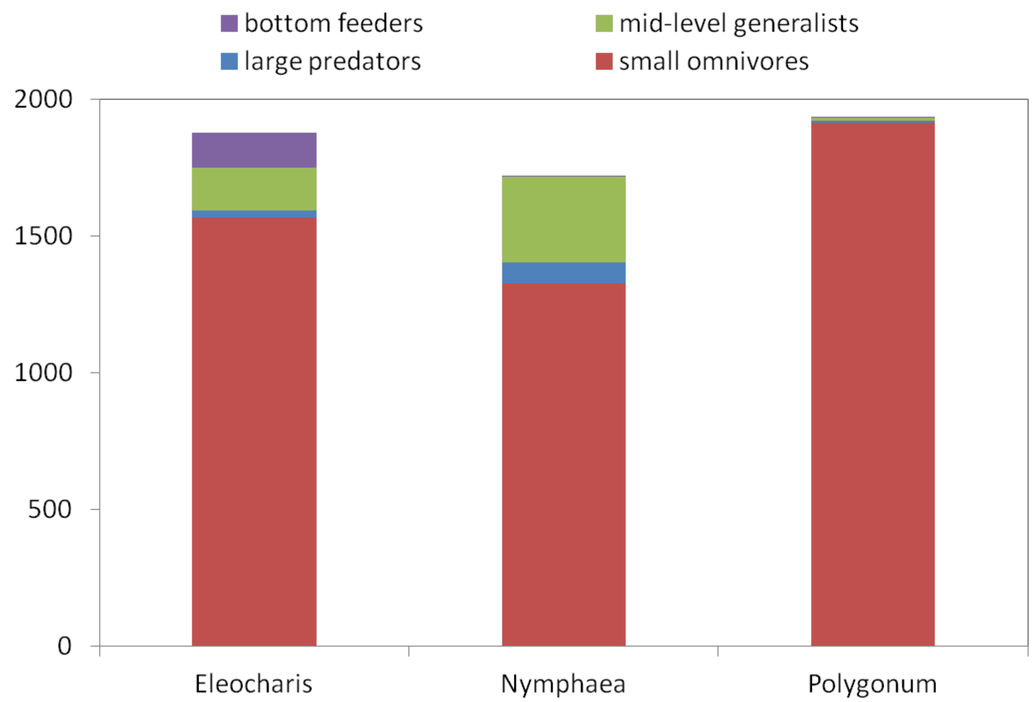


Figure 8-44. Numbers of fish captured in sampled vegetation types. Fish are grouped by their general feeding niche (Ross, 2001). Large predators include species such as Florida gar and bowfin. Small omnivores include the eastern mosquitofish, killifish, and shiners. Mid-level generalists are mostly sunfish species, while bottom-feeders are catfish.

NATIVE FLORIDA APPLE SNAILS

The District has been involved in investigating methods of large-scale apple snail production to be used to assist local apple snail population recovery since 2007. While working in partnership with Harbor Branch Oceanographic Institute at Florida Atlantic University, culture protocols were established for raising animals under laboratory conditions. However, production under these culture methods is limited by space and is labor intensive, making the program potentially cost prohibitive. In an attempt to lower production costs, District scientists evaluated the feasibility of an in situ culture program in which snails were raised in enclosures constructed within a local wetland and egg clutches laid within the enclosures were harvested and hatched into large outdoor tanks. The primary goals of this feasibility program were twofold: (1) to determine if this more extensive and potentially less labor intensive method was an effective means of producing a large number of animals, thereby reducing production costs, and (2) to produce snails for use in stocking experiments to determine the efficacy of stocking adult apple snails (i.e., does stocking animals lead to the establishment of self-sustaining populations?). To meet these objectives, District staff monitored total clutch production within each enclosure, analyzed egg clutch characteristics for comparison to wild clutches, estimated the average survival from hatchling to adult within each enclosure, and established a number of experiments in large enclosures examining the survivability and reproduction potential of stocked newly hatched and larger juvenile/adult snails (results to be reported in the 2014 SFER).

Methods

Nine enclosures were constructed within the Lemkin Creek Isolated Wetland, which is a 33-acre marsh located just north of Lake Okeechobee (see the SFER 2012 – Volume I, Chapter 8 for more detail on construction methods). These enclosures were initially stocked with three different densities of adult Florida apple snails (0.5, 2, or 4 snails per m^2; hereafter referred to as low, medium, and high density, respectively) on April 13, 2011. These snails were small in size (20–25 mm), but sexually mature. Post stocking, the enclosures were visited every two weeks throughout the remainder of the apple snail breeding season (May–October) in 2011. District staff continued to monitor enclosures throughout the following breeding season as well, beginning with the onset of breeding in March 2012. All egg clutches within the enclosures were enumerated. Egg clutches laid on artificial substrates or on natural substrates within arms' reach of the enclosure walls were collected and transported to an outdoor mesocosm facility where the eggs were hatched and reared. Egg clutches laid on the walls of the enclosure or on substrate toward the center of the enclosure beyond arms reach were counted but not collected. These clutches provided the source for the 2012 adult population ensuring the continuation of reproduction during the next breeding season.

At the mesocosm facility, egg clutches were analyzed to determine the number of eggs per clutch and the hatch rate of each clutch. Hatch rate was determined by calculating the number of eggs that hatched divided by the total number of eggs within the clutch. Mean clutch size and mean hatch rate were estimated for each collection date during the 2011 and 2012 breeding seasons.

Since the enclosures were stocked with different densities of animals, it was necessary to standardize production data within each enclosure to reflect the number of clutches produced per female. This allowed for a direct comparison between treatments to determine whether stocking density affects overall reproductive capacity.

To determine the population density of each enclosure during the second breeding season, a capture-mark-recapture study was undertaken at the beginning of the 2012 breeding season. Thirteen pyramid traps were set up within each enclosure. These traps have been shown to be especially successful in trapping adult apple snails during times when animals are highly mobile, as they are during the breeding season (Darby et al., 1997). Traps were checked three days post set and the snails within the traps were marked and replaced within the enclosures. The traps were checked again three days later. The population within each enclosure was then calculated using the Lincoln-Peterson index:

$$N = mn/r$$

Where N is the population to be estimated, m is the number of animals marked and released from the first trapping event, n is the total number of individuals captured during the second trapping event, and r is the total number of marked animals that were recaptured during the second trapping event.

By estimating the population of each enclosure in 2012, it was possible to calculate the average survival of hatchlings from the 2011 season that successfully grew to adulthood to breed in 2012. The number of clutches that hatched into the enclosures in 2011 were enumerated and multiplied by the average clutch size and the average hatch rate to get an estimate of the total number of animals hatched into each enclosure. To estimate survival, the total number of adults estimated to be in each enclosure in 2012 (obtained from the mark-recapture study) was divided by the number of juveniles estimated to have hatched into each enclosure in 2011.

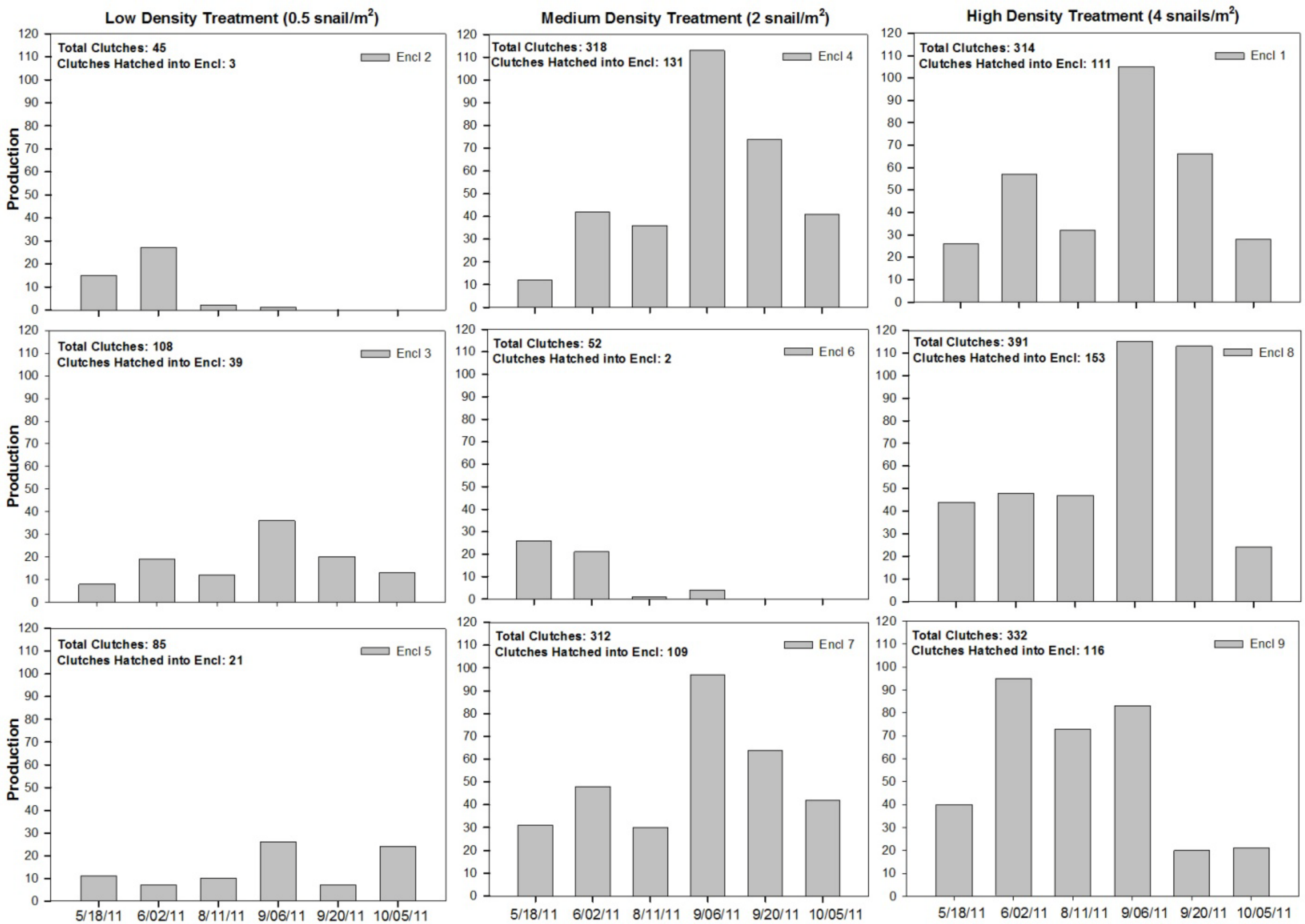
The location of this feasibility study was chosen primarily based on the anticipated hydrologic stability of the Lemkin Creek marsh in which, because of its structure, source water was expected to remain inundated and at depths suitable for apple snail reproduction at all times. Despite these conditions, 2011 was the driest dry season on record since the 1930s and Lemkin Creek marsh did dry out. The marsh was completely dry by the beginning of June 2011 and remained that way for two months. During the dry period, live adult apple snails were found buried in the sediment within the enclosures. However, research has indicated that there is a direct correlation between time since drydown and mortality, with smaller animals being more susceptible to death (Darby et al., 1997). Since the marsh dried out one month following stocking, it is likely that snails hatched into the enclosures during that first month did not have sufficient time to grow large enough to survive such dry conditions. Therefore, for this analysis, juveniles hatched into the enclosures before June 2011 were not taken into account. If any juveniles did survive from this time period it was most likely a low number and should minimally bias any of the population analyses in this report.

Results and Discussion

Habitat suitability within the Lemkin Creek enclosures appeared to be adequate to sustain long-term apple snail growth and reproduction (**Figures 8-45** and **8-46**). Snails stocked into the enclosures began reproducing immediately, albeit slowly, in 2011, and gradually increased production as the breeding season progressed (**Figure 8-45**). The slow start to the season was likely related to the small initial size of the stocked snails. Later in the season, all snails had visibly grown indicating that food resources within the enclosure were sufficient to maintain growth. Similarly, apple snails again began reproducing during the 2012 breeding season signifying that juvenile snails hatched into the enclosures in 2011 had grown to become reproductive adults the following year as the normal life span for an apple snail is 1 to 1.5 years.

In 2011, a total of 1,957 egg clutches were produced in all of the enclosures combined. The average clutch size was 25 eggs in 2011 (average range: 18–35). This equates to approximately 50,000 eggs produced over a 14-week time period during the first production season. This number was far exceeded during the 2012 season; in the first 12 weeks (March to May), 3,000 egg clutches had already been produced with many months of breeding remaining. The average clutch size for this timeframe was 39 eggs (average range: 33–45), which equates to roughly 117,000 eggs.

Under laboratory conditions hatch rates are usually much lower than they are in the wild. Given that the stocked snails were cultured animals and were also stocked into the enclosures at high densities for natural conditions, it was anticipated that hatch rates in the enclosures would behave similarly. However, contrary to this expectation, hatch rates among all treatments were comparable to the hatch rates of wild egg clutches. The average percent hatch rate across all treatments was 69 percent in 2011 (range: 68–73) and 76 percent in 2012 (range: 69–85). Egg clutches collected from various lakes since 2007 have had an average hatch rate of 82 percent (range: 61–89). So, neither stocking density nor habitat quality within the enclosures appears to have affected hatch rate making the clutches produced by animals in the enclosures comparable to wild egg clutches. . . . . . .



1622 **Figure 8-45.** Total number of egg clutches produced over time in each of the nine Lemkin Creek enclosures in 2011.
1623 Also noted are the total number of egg clutches hatched into each enclosure during the 2011 breeding season.

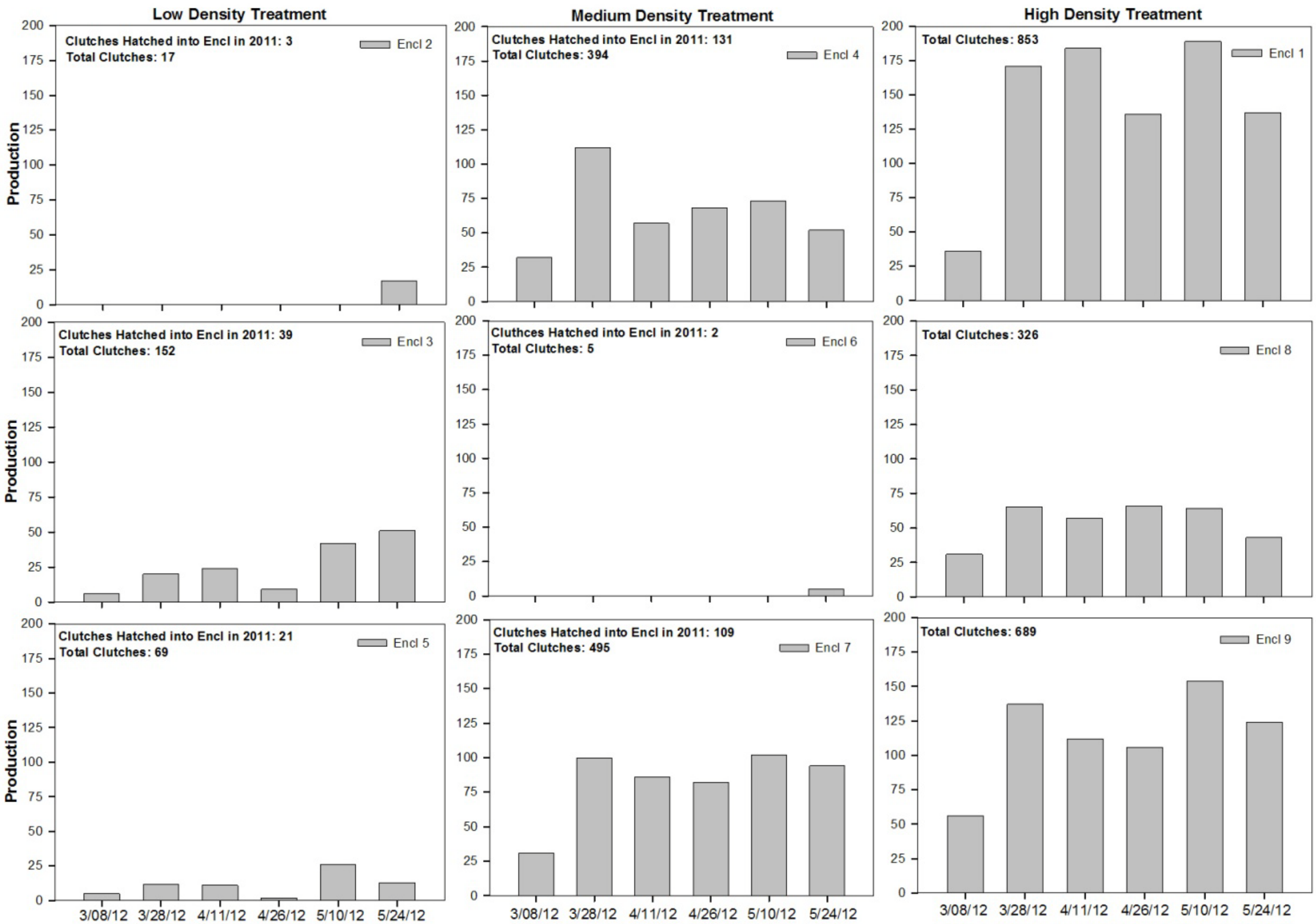


Figure 8-46. Total number of egg clutches produced over time in each of the nine Lemkin Creek enclosures in 2012. Also noted are the total number of egg clutches hatched into each enclosure during the 2012 breeding season.

Despite the marsh being completely dry for two months in 2011, the stocked adult snails seemed to have had high survival throughout this period, as evidenced by peak reproduction occurring in early September shortly after the marsh was re-inundated with water (**Figure 8-45**). Typically, peak reproduction for apple snails occurs in April and May given adequate hydrologic conditions (Darby et al., 1997). We did not see this trend in 2011 due to the time of stocking (the end of April), the small initial size of the stocked animals, and the poor hydrologic conditions immediately following stocking. The timing of peak reproduction in 2011 illustrates that the reproductive season has the potential to be prolonged if hydrology is restored or remains at a level conducive to breeding. This flexibility could greatly benefit apple snail populations by allowing significant production to occur even if conditions are poor early in the season. In 2012, peak reproduction was not as clearly evident since the analysis only encompassed the first part of the season (**Figure 8-46**). Clutch production was high and steady throughout April and May, but will likely taper off as the season comes to an end, which is more representative of the typical reproductive season.

For most collection dates throughout the 2011 breeding season, clutch production per female was lower than the expected one clutch per week, the exception being during the reproduction peak in September (**Figure 8-47**). Across all density treatments, before and after September, 81 percent of the females produced less than 0.75 egg clutch per week (the average being 0.52 clutches per week), whereas during peak reproduction only 27 percent of the females produced less than 0.75 egg clutches per week (the average being 0.97 clutches per week).

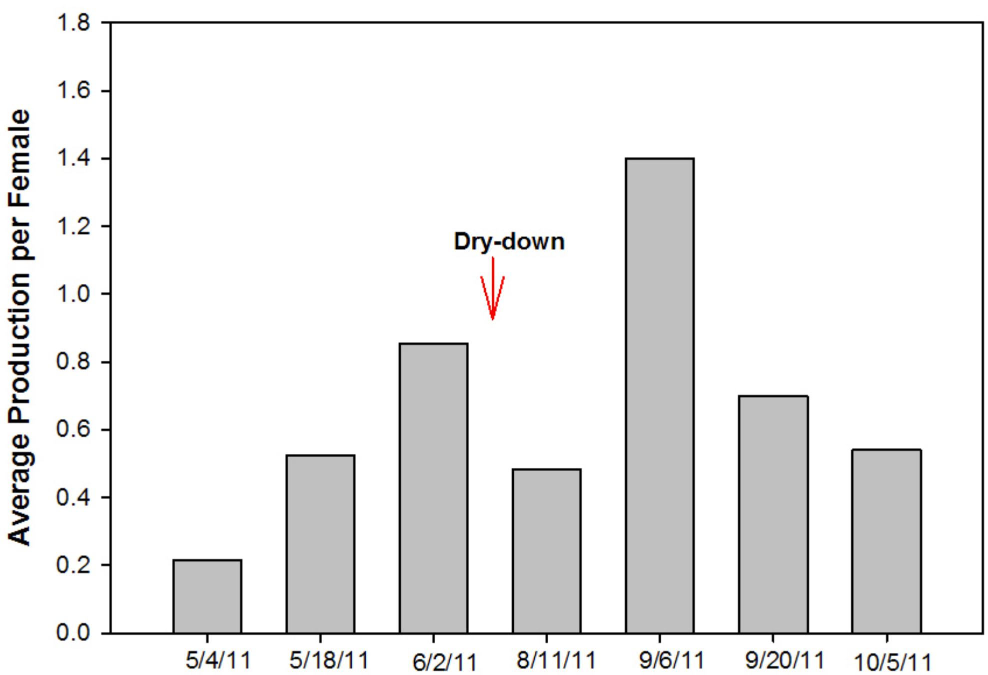


Figure 8-47. Production per female averaged across all nine enclosures for each egg clutch collection date during the 2011 breeding season. The marsh was completely dry from the beginning of June until the end of the July during which time there was no production in any of the enclosures.

It was more difficult to calculate clutch production per female for the 2012 breeding season because the total number of females within each enclosure was unknown. Population size was estimated in each enclosure in 2012 using the Lincoln-Peterson capture-mark-recapture method and the number or reproductive female was based on an assumed 1:1 sex ratio. Using these population results, production per female was rarely less than 0.75 clutches per week, the only exception being the first week of reproduction (**Figure 8-48**). Moreover, in many instances production exceeded two clutches per female per week (clutches/female/wk). The disparity in clutch production per female between 2011 and 2012 may be related to the difference in the density of egg laying substrate. When the enclosures were built in 2011, they were free of any emergent vegetation. Instead, 100 bamboo stakes were placed in each enclosure to provide egg laying substrate that could conveniently be removed and collected. Conversely, in 2012, the enclosures were full of emergent vegetation, which the snails used almost exclusively as laying substrate. Thus, it is possible that production during the 2011 breeding season was limited by available egg laying substrate. This also illustrates that apple snails may lay much more than one egg clutch per week, which has been the accepted average in the literature until now.

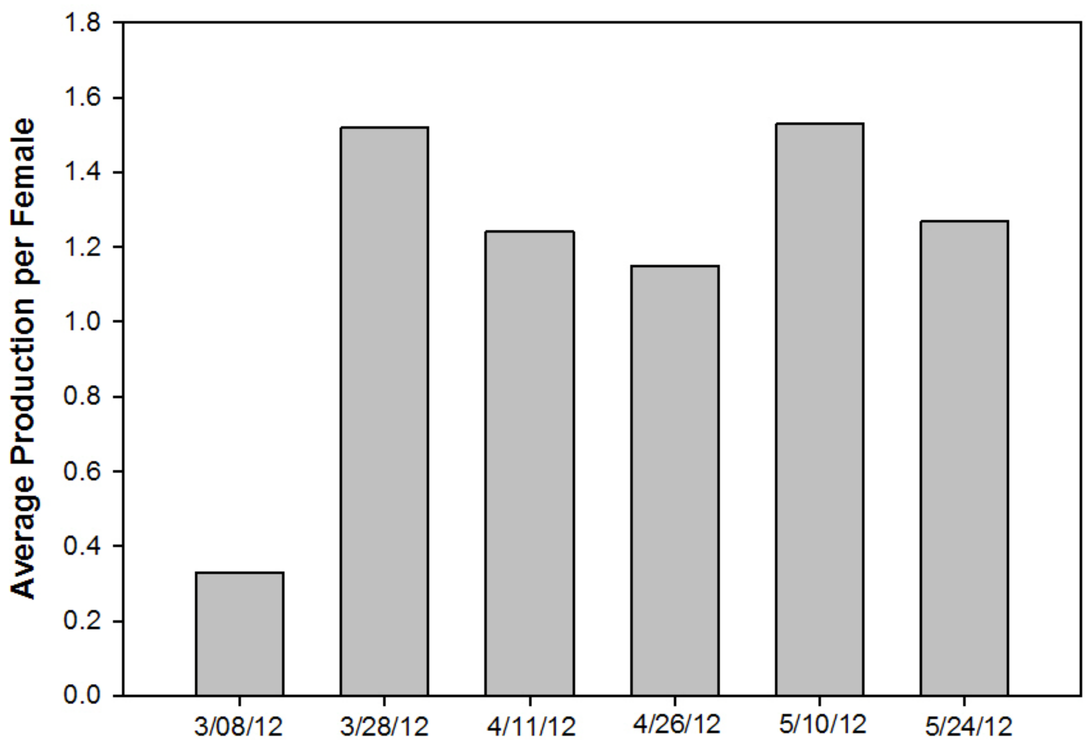


Figure 8-48. Production per female averaged across all nine enclosures for each egg clutch collection date during the 2012 breeding season. For the purposes of this report, only data collected to the end of May 2012 is presented.

In laboratory experiments conducted at Harbor Branch Oceanographic Institute, stocking density was found to negatively affect production within tanks (Posch et al., 2012). Similarly, in the wild, snail densities are low, typically averaging 0.5 to 1 snails per m^2. Stocking density in the enclosures was low when compared to laboratory standards (50 to 100 snails per m^2), but high compared to what is typically found in natural habitats. When production per female was compared among the three density treatments (low, medium, and high), there was not a significant difference at the $\alpha = 0.05$ level ($p = 0.053$). Upon closer inspection of the data, the mean production per female in the low density treatments (0.88 clutches/female/wk) was almost twice as much as it was in the high density treatments (0.46 clutches/female/wk) and this was significantly different ($p = 0.017$). However, neither the low and medium treatments nor the medium and high density treatments were significantly different from each other, which accounts for the overall non-significance of the model. These results suggest that to maximize production on a per female basis, it would be best to stock at densities closer to what is typically found under natural conditions. However, if the goal is to maximize total production per enclosure, then stocking at the medium or high rate is the best strategy.

The capture-mark-recapture study that was initiated within the enclosures at the beginning of the 2012 breeding season indicated that juvenile survival to adulthood was just high enough to provide replacement. This was confirmed by the fact that seven out of nine enclosures had reproduction the following year suggesting that apple snails can establish self-sustaining populations upon stocking, at least in the absence of high predation pressure. Survival of hatchlings to adulthood ranged from 1.5 to 4 percent in the experimental enclosures.

It remains to be determined whether directly stocking egg clutches on substrates into the environment, or providing some degree of controlled hatching and rearing prior to stocking is the best approach to stock enhancement efforts. As noted above, several studies are now under way to determine the efficacy of a number of these options.

WADING BIRDS

Wading bird foraging has been monitored in Lake Okeechobee since 2010. This monitoring provides water managers with real-time data on habitat suitability and habitat utilization for wading birds as a function of the interaction between climatology and water management decisions, and allows for a general overall assessment of ecological conditions within the lake. It also provides important supporting data for the annual Lake Okeechobee wading bird nesting surveys carried out by Florida Atlantic University.

Methods

Wading birds surveys were conducted from December 2011 through June 2012 along east-west transects established at 2-kilometer intervals throughout the entire littoral zone of Lake Okeechobee. Additional survey methods are described in detail in the 2012 SFER – Volume I, Chapter 8.

Results

The dry season began in December 2011 at a lake stage of 13.7 ft NGVD with approximately 75 percent of the marsh being inundated with water. Throughout the season, stage exhibited a strong and steady recession (**Figure 8-49**) creating conditions that should have been conducive to wading bird foraging. However, during surveys conducted from December through March the number of foraging flocks greater than 50 birds was minimal; ranging from 4 to 9 flocks each month. While foraging did increase slightly as the season progressed (peaking at 22 flocks in April and May), the marshes of the lake were highly underutilized throughout the season.

Mean wading bird flock size throughout the season ranged from 143 to 373 birds. While this seems somewhat variable, a closer inspection of the data indicated that the means were, at times, subject to inflation by the presence of one or two large foraging flocks during a survey (**Figure 8-49**). In general, the sizes of the foraging flocks in 2012 were smaller than what they were in previous years. The data indicated that 44 percent of the foraging flocks consisted of 100 to 400 birds (**Figure 8-50**). Likewise, 44 percent were comprised of 50 to 100 birds. In 2011, only 20 percent of the flocks were this small. In 2012, there were only 11 flocks the entire season that exceeded 500 birds and only two of those had more than 1,000 birds. The total number of birds foraging in the lake peaked in May at 4,100 (**Figure 8-51**).

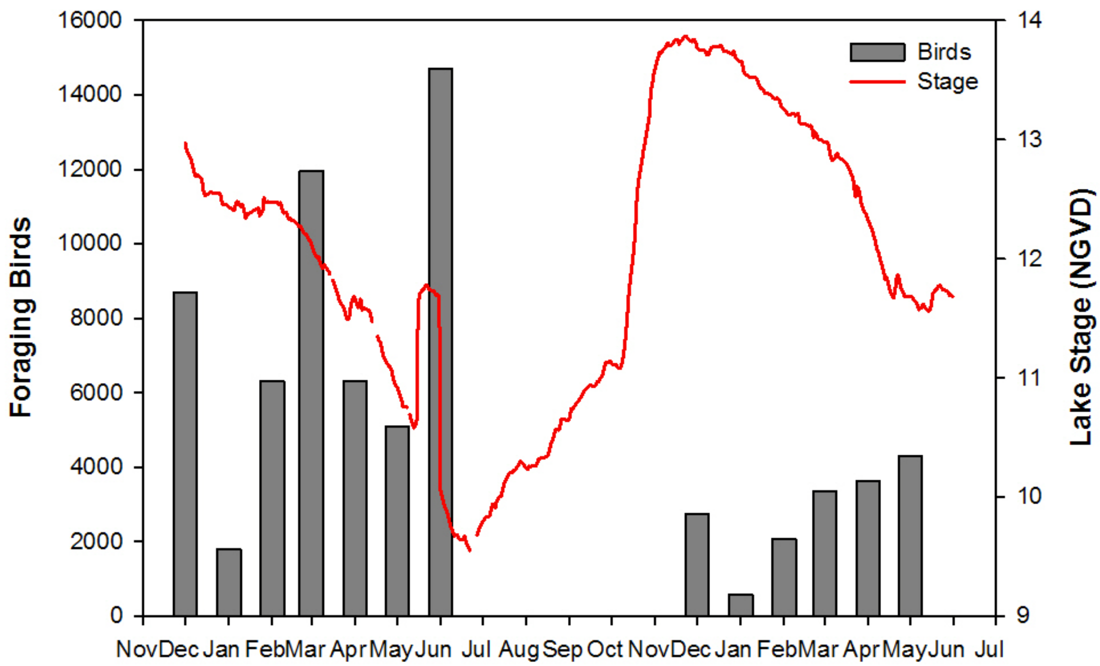


Figure 8-49. A comparison of the total number of foraging birds surveyed each month in 2011 and 2012 in relation to lake stage.

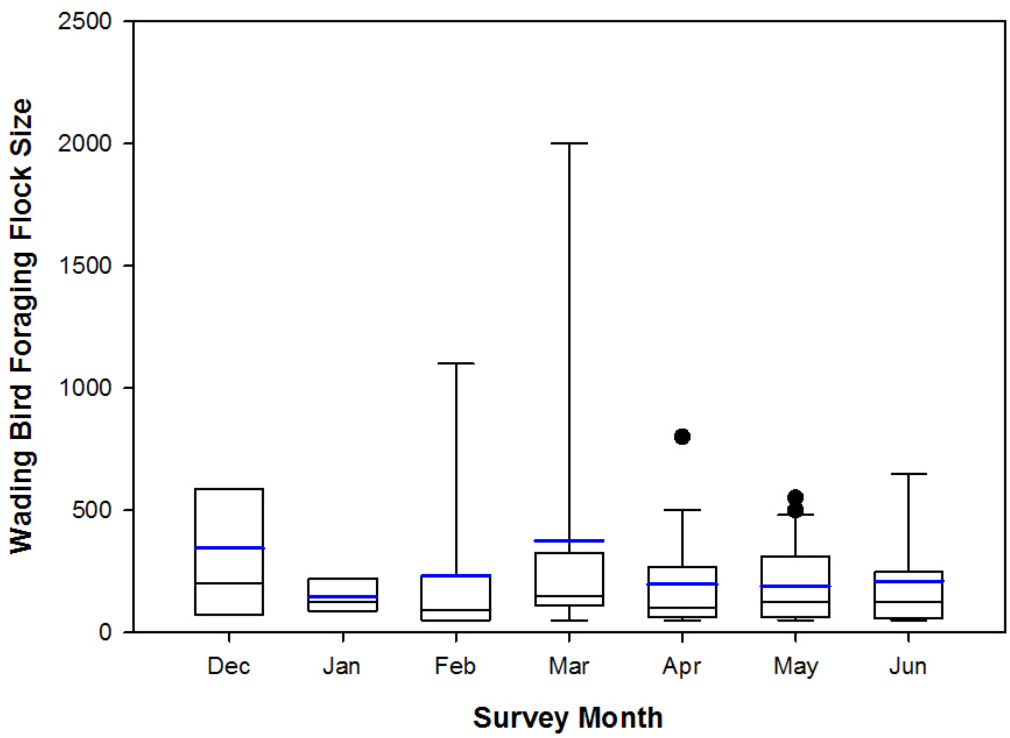


Figure 8-50. A comparison of wading bird foraging flock size by month for the 2012 wading bird breeding season. Boxes encompass 50 percent of the data while whiskers (standard error) encompass 90 percent of the data. The solid blue solid line is the mean flock size and the solid black line is the median; black dots are outliers. December and January boxes are lacking whiskers because there were not enough foraging flocks in those months to compute higher percentiles.

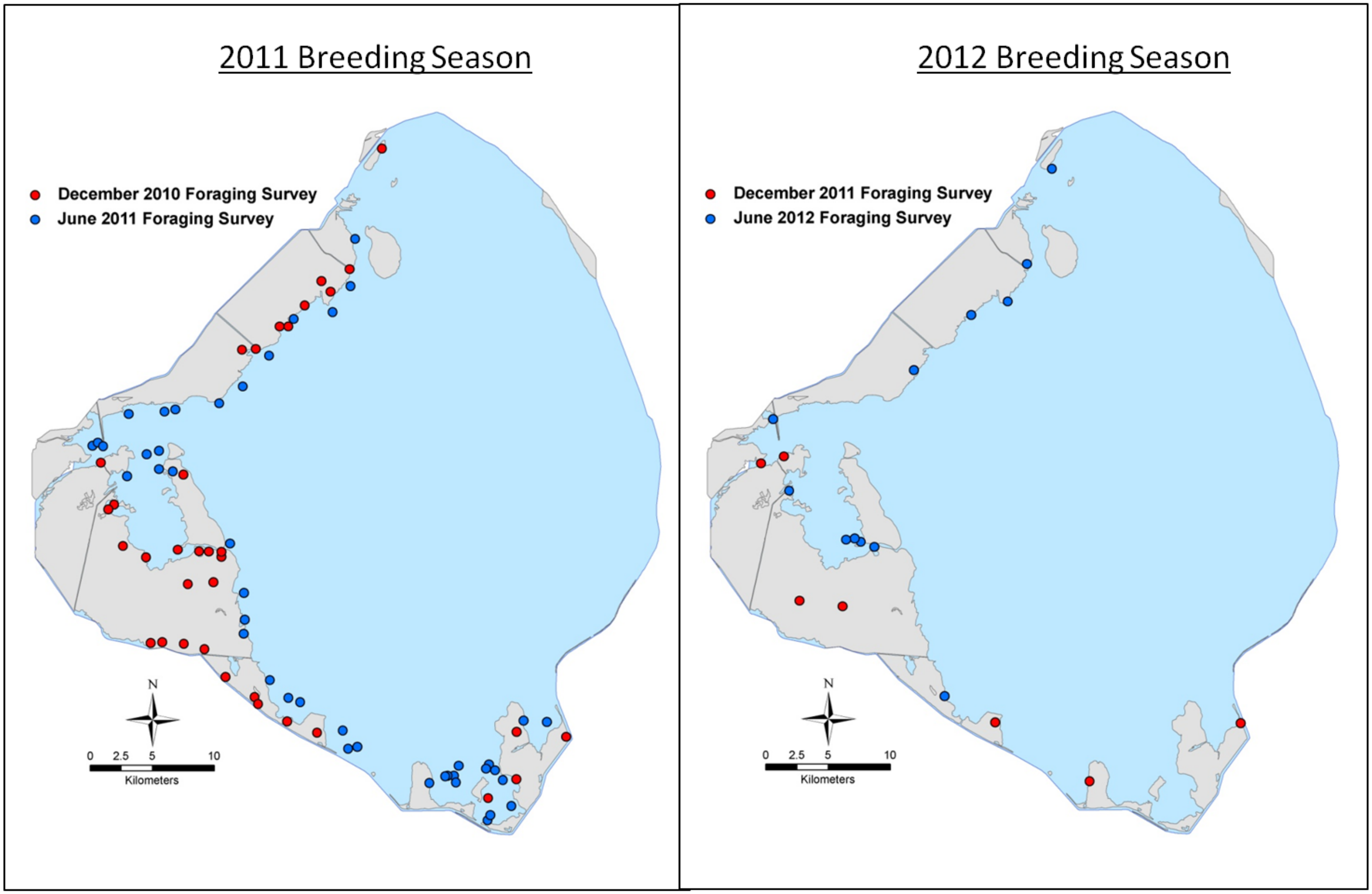


Figure 8-51. A spatial comparison of wading bird foraging locations in December and June 2012.

The most probable explanation for the underutilization of Lake Okeechobee by birds during the 2012 breeding season is that there was low prey availability in the marshes surrounding the lake within the Herbert Hoover Dike. The 2011 hydrograph (**Figure 8-49**) indicates that lake stage was at 11 ft NGVD beginning in March and continued to decline until July ending at a lake stage of 9.5 ft NGVD. At these stages, 25 percent or less of the littoral zone is inundated with water. The onset of the wet season began in mid-July 2011, but lake stage did not reach a level that would inundate more than 50 percent of the marsh until November 2011. Given that most, if not all, of the marsh had been dry in excess of six months, it is not surprising that the prey base would be minimized. A depressed prey base is a common occurrence in the Everglades following drought where there is typically a time lag between when water becomes available and fish begin to spawn.

Similar to previous years, the majority of the flocks were mixed species; however, most flocks were dominated by great egret (*Ardea alba*) rather than white ibis (*Eudocimus albus*) or snowy egret (*Egretta thula*) as was the case in 2011. While these birds were still present in most flocks, it was in much smaller numbers. These two species are known to select foraging patches throughout the landscape with high prey availability (Gawlik, 2002). Their lack of abundance in the foraging flocks located in 2012 is another indication that prey availability was probably low throughout the Lake Okeechobee littoral zone.

In 2011, birds foraged in a predictable pattern, following the receding water across the littoral zone. In 2012, this pattern was mostly absent. Instead, birds were primarily found foraging in and around cuts and tributaries flowing into the lake and to a smaller degree, in small drying pockets within the littoral zone (**Figure 8-51**). The location of the foraging flocks coupled with the smaller size of each individual flock, again, are good indicators that wading birds had difficulty finding patches with high prey availability in the littoral zone of the lake.

Poor foraging conditions on the lake also resulted in poor nesting success for the 2012 breeding season. Although wading bird nest effort was reasonably high considering the poor foraging conditions (4,500 nests located within 16 colonies; J. Chastant, Florida Atlantic University, personal communication), the number of nests that ultimately fledged birds was minimal. Despite the low number of fledglings produced on Lake Okeechobee in 2012, this was one of the few places in the Greater Everglades landscape that had successful nesting, albeit at low numbers.

Heavy rains occurring toward the end of April resulted in a reversal in the seasonal hydrologic recession causing widespread partial or complete abandonment of most colonies throughout the Everglades. The recession rate in Lake Okeechobee was not similarly affected by these rains since the large size of the lake acts as a buffer against all but very large localized and regional rain events; especially, as in this year’s case, if there is limited precipitation in the Kissimmee Valley. Therefore, colonies residing within the lake were not as affected by these rains as were other regions. Unfortunately, poor foraging conditions throughout the season led to abandonment of many of the colonies despite the minimal stage fluctuation.

LAKE ISTOKPOGA SUBMERGED AQUATIC VEGETATION

The distribution and areal coverage of SAV in Lake Istokpoga was evaluated during spring 2012. The lake was equally divided into 487 grids each covering an area of 500 m by 500 m (25 ha). Thirty-two of the grids were located on islands and were not accessible by boat. Sampling occurred near the center of the accessible grids and was considered representative of the grid. Plant presence or absence, plant density, and species composition were recorded. SAV was identified in 215 of the 447 sampled grids (48 percent) (**Figure 8-52**). The most commonly observed plants included hydrilla, an invasive exotic, and the native species tape grass. These plants occurred (either by themselves or in conjunction with other species) in 73 and 32 percent of the vegetated sites, respectively. Although hydrilla was present in 73 percent of the sampled, sites its density was generally sparse. Other observed but less common species included naiad (*Najas* spp.), bladderwort (*Utricularia* spp.), pondweed (*Potamogeton illinoensis*) and coontail (*Ceratophyllum* spp.*)*.

Compared to the 2011 SAV sampling event, the total acres of plants was slightly reduced (11,349 ac in 2012 compared to 12,970 total ac in 2011). However, both the occurrence of hydrilla and its average density (24 dense and 18 moderate in 2011 compared to 4 and 5 sites, respectively, in 2012) showed definite improvement; probably as a result of FWC's ongoing hydrilla management activities on Lake Istokpoga.

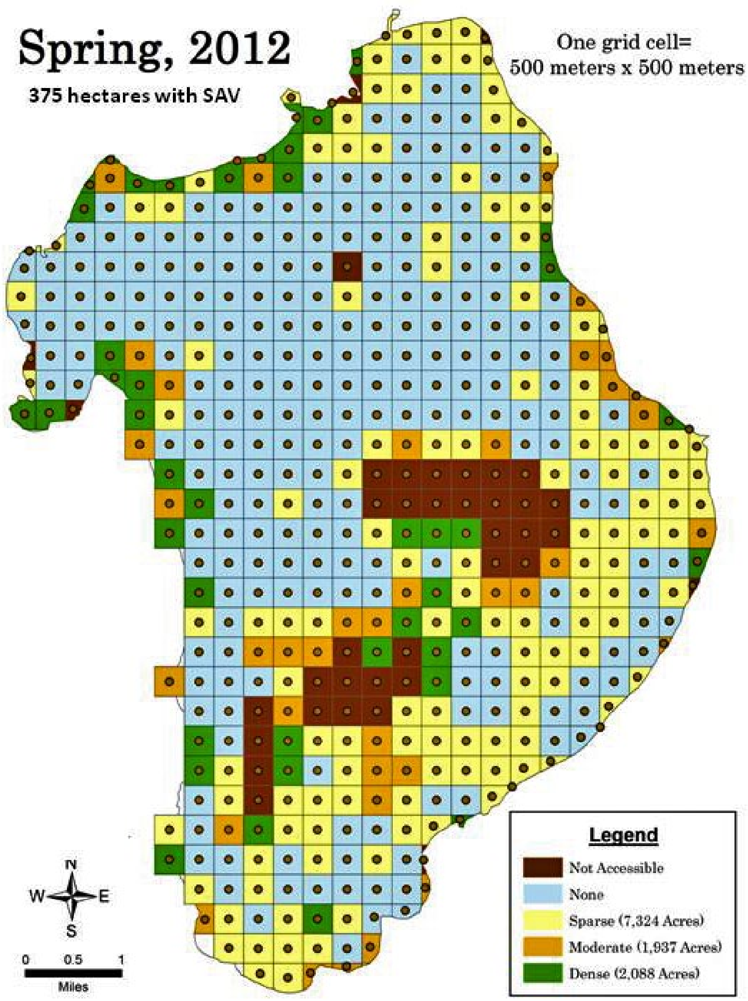


Figure 8-52. Distribution of 375 hectares of SAV in Lake Istokpoga in spring 2012.

APPROPRIATIONS/EXPENDITURES

The FY2002- FY2012 summary of State of Florida funding appropriations and expenditures for the LOWPP is presented in **Table 8-14**.

Table 8-14. State funding appropriations and expenditures for the LOWPP for Fiscal Years 2002–2012 (FY2002–FY2012) (October 1, 2001–September 30, 2012). [Note: FY2012 financial data will be available for the final report.]

Appropriation Year	SFWMD Appropriation	Expended to Date	Available
FY2001 Florida Department of Environmental Protection (FDEP) contract SFW11 (1519G)[a]	$8,500,000	$8,478,572	
FY2001 FDEP Contract SFW12 (1591G)	$15,000,000	$15,000,000	
FY2001 South Florida Water Management District (SFWMD) Total	**$23,500,000**	**$23,478,572**	**$0**
FY2002 FDEP Contract SFSWP1 (1748)	$10,000,000	$10,000,000	
FY2002 SFWMD Total	**$10,000,000**	**$10,000,000**	**$0**
FY2003 FDEP Total Maximum Daily Load Implementation Funds	$850,000	$850,000	
FY2003 SFW31 (1769) Grant 42	$7,500,000	$7,087,118	$412,882
FY2003 SFWMD Total	**$8,350,000**	**$7,937,118**	**$412,882**
FY2005 SFW51 – Nubbin Slough G44	$4,300,000	$2,366,158	$1,933,842
FY2005 SFW61 Grant 46	$5,000,000	$2,087,815	$2,912,185
FY2005 – FDEP Nubbin Slough/Lake Okeechobee Fast Track (LOFT) G3	$3,300,000	$2,174,912	$1,125,088
FY2005 – Hydromentia	$1,800,000	$1,800,000	
FY2005 SFWMD Total	**$14,400,000**	**$8,428,884**	**$5,971,116**
LOFT Projects – Reimbursable Expenditures G4	$25,000,000	$25,000,000	
101 Ranch 17.2-ac Reservoir	$42,000	$42,000	
C&B Farms Trail Water Recovery	$93,600	$93,600	
101 Ranch 44-ac Reservoir	$30,864	$30,864	
Stormwater Irrigation	$51,920	$51,920	
FY2006 Sub-basin Monitoring Network	$225,000	$225,000	
FY2006 SFWMD Total	**$25,443,384**	**$25,443,384**	**$0**
FY2007 Hydromentia – Algae Turf Scrubber® – FDEP G41	$750,000	$750,000	
FY2007 Hydromentia – Algae Turf Scrubber® – Florida Department of Agriculture and Consumer Services (FDACS) G39	$221,610	$221,610	
LOFT Projects – Reimbursable Expenditures G66	$24,925,000	$24,925,000	
Community Budget Issue Requests – Taylor Creek PL566 and Alternative Storage/Disposal of Excess Water G47	$6,200,000	$3,754,876	$2,445,124
FY2007 Cody's Cove and Eagle Bay Grant 52	$2,478,548	$2,478,548	
Indiantown Citrus Growers Association G54[b]	$287,808	$267,853	
Raulerson & Sons Ranch Stormwater Reuse Alternative Water Use G56	$330,000	$330,000	
FY2007 SFWMD Total	**$35,192,966**	**$32,727,887**	**$2,445,124**
FY2008 Sub-basin Monitoring Network	$225,000	$225,000	
FY2008 SFWMD Total	**$225,000**	**$225,000**	**$0**
FY2012 Lake Okeechobee Predrainage Characterization	$175,000		$175,000
FY2012 SFWMD Total	**$175,000**	**$0**	**$175,000**
Grand Total – SFWMD State Appropriation – 221	**$117,286,350**	**$108,240,845**	**$9,004,121**
FY2001 FDACS Appropriation	$15,000,000	$15,000,000	
FY2005 FDACS Appropriation	$5,000,000	$5,000,000	
FY2005 FDEP Pahokee Wastewater Treatment Plan	$700,000	$700,000	
FY2007 FDACS Appropriation	$3,900,000	$3,900,000	
FY2008 FDACS Appropriation	$6,000,000	$6,000,000	
FY2009 FDACS Appropriation	$3,000,000	$3,000,000	
FY2010 FDACS Appropriation	$3,000,000	$3,000,000	
FY2011 FDACS Appropriation	$3,000,000	$3,000,000	
FY2012 FDACS Appropriation	$6,000,000	$2,000,000	$4,000,000
Total Outside Agency State Appropriation	**$45,600,000**	**$41,600,000**	**$4,000,000**
Save Our Everglades Trust Fund			
FY2008 Northern Estuaries (NE) – Caloosahatchee, St. Lucie, and Lake Okeechobee) – Grant 58	$2,623,146	$2,623,146	
FY2008 NE – Lake Okeechobee Protection Project – Grant 59	$31,045,000		$4,182,132
LOFT – Lakeside Ranch Stormwater Treatment Area (STA)		$20,057,155	
NE Water Storage Disposal Projects		$6,254,657	
Technical Plan		$551,056	
FY2008 Biological Wetland and Chemical/Hybrid Technologies - Grant 62	$5,000,000	$5,000,000	
FY2009 NE – Best Management Practices (BMPs) – Grant 96	$3,009,120	$3,009,120	
FY2010 NE – BMPs – Grant 94	$1,500,000	$1,500,000	
FY2011 NE – BMPs – Grant 94	$1,500,000	$1,500,000	
FY2012 NE – Lake Okeechobee Protection Plan – Grant 99	$6,178,642		$6,178,642
LOFT – Lakeside Ranch STA			
NE Water Storage Disposal Projects			

Total – Save Our Everglades Trust Fund – 412	**$50,855,908**	**$40,495,134**	**$10,360,774**
Grand Total – Lake Okeechobee	**$213,742,258**	**$194,335,980**	**$19,364,895**

a. $21,428 returned to the state in FY2010

b. Reimbursement grant expired March 2010; $19,955 balance of grant not used

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